SEWAGE WORKS JOURNAL

VOL. XXI JANUARY, 1949 No. 1

Special Features

Sewer Slime Control—Beardsley

Industrial Association Activities—Wisely

Wool Scouring Waste Treatment—McCarthy

Stream Standards—Streeter

Nuclear Fission Wastes—Welman and Gorman

OFFICIAL PUBLICATION OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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Please remit immediately upon receipt of the first dues notice from your Member Association Secretary.

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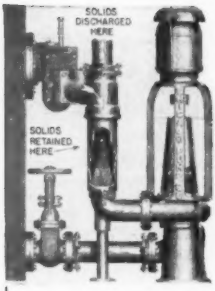
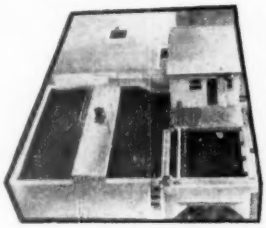
325 Illinois Bldg. **Champaign, Ill.**

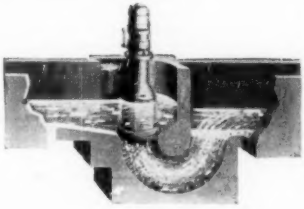


FLUSH-KLEEN SEWAGE EJECTORS: Actual clog-proof pumping of raw sewage or any liquid containing coarse and stringy matter is attained by the Flush-Kleen, because a screen in the influent pipe protects the impeller from all solids. Incoming solids are retained on the screen. When the pump starts the screen is backwashed as the solids are carried out the discharge pipe.

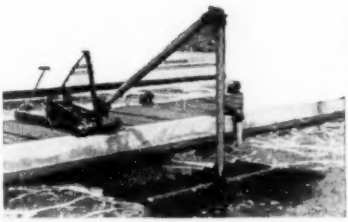
Efficiency .. Economy .. Ease .... of Operation With this "Chicago" Equipment



"PACKAGE" SEWAGE PLANTS: Flexibility is the design keynote in the Package plant. Not a cut-down version, but planned and developed for the smaller community, housing development, airport or industrial plant. Populations from 100 to 5000 can be served with these plants.



COMMINUTORS: The Comminutor eliminates sewage screenings handling and disposal, with its accompanying foul odors, fly nuisance and unsightliness. Installed in the influent channel it automatically screens and cuts sewage solids without removal from the line of flow.



SWING DIFFUSERS FOR AERATION TANKS: For the larger Activated Sludge Sewage treatment plants the Chicago Wide Band Air Diffusion System with swing diffusers provides optimum tank circulation without center coring. The wide band of fine bubbles allows greater contact between air and mixed liquor, providing greater oxygen absorption.

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Flush-Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs, Water Seal Pumping Units, Samplers.

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SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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Sewage Works Journal is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

WHY METER SEWAGE?

IN A NUTSHELL, HERE'S THE ANSWER:*

METERING ***INDICATES THE PRESENCE OF UNUSUAL QUANTITIES OF SURFACE OR GROUND WATER.***

METERING ***FURNISHES INFORMATION ON WHICH TO ESTIMATE FUTURE FLOWS AND THE NEED FOR ADDITIONAL TREATING FACILITIES.***

- Sewage flow per capita daily
- Detention period in tanks
- Total solids handled
- Sludge per million gallons of sewage
- Cost of pumping sewage per million foot-gallons and treatment per million gallons
- Sewage treated per unit area — by trickling filters, contact beds, intermittent sand filters, sedimentation tanks, etc.
- Organic load, hourly and daily, on sewage plant and the water receiving effluent

METERING ***INDICATES OPERATING PROCEDURE.***

- Need for by-passing sewage
- Quantity of chemicals for coagulating purposes
- Quantity of chlorine or hypochlorite of lime required
- Quantity of activated sludge to return to aeration tanks
- Quantity of air for grease removal and activated sludge process
- Number of pumps and treatment units to operate

* * *

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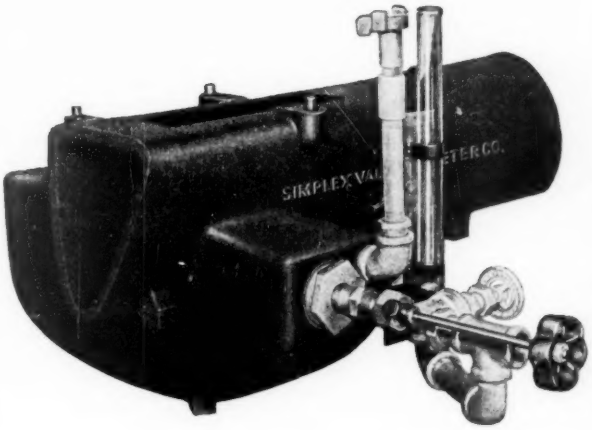
MEASURES
EXTREME LOW FLOW
OF WATER, SEWAGE AND
INDUSTRIAL LIQUIDS



Simplex Type "S" Parabolic Flume is designed to measure accurately flows of all kinds of liquids through partially-filled pipes, sewers or channels where free-flowing conditions exist. The Simplex "S" Flume permits measurement of fluid under low head conditions and with small head loss . . . needs only slight free fall of the liquid at flume outlet. Write for bulletin and full information to the Simplex Valve & Meter Company, 6719 Upland Street, Philadelphia 42, Pa.

SIMPLEX
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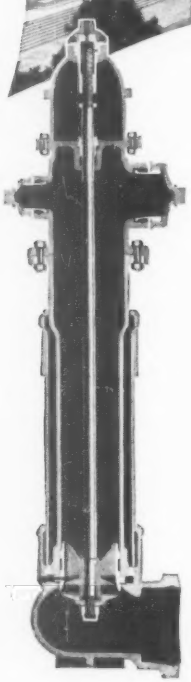

WILMINGTON, DEL.

"One of America's Safest Cities"
THE MATHEWS FIREMEN SAY

SIMPLE LOGIC! For Wilmington is protected by Mathews Modernized Hydrants, which means safety plus—for two big reasons. First, the hydrant need not be out of commission long in case of an accident. All the working parts are contained in a removable barrel which can be replaced in a few minutes without excavating.

Secondly, Mathews are designed for troublefree service—as generations of use have proved. Water cannot reach the thread and rust it. A shield operating nut, capping the revolving nut, keeps out rain and dust and provides free, quick action at all times. These and other features combine to make a hydrant in which there is just about *nothing to go wrong*.

Send for interesting, descriptive literature and read in detail how the Mathews Modernized Hydrant can furnish the safety plus you are looking for.

OTHER MATHEWS FEATURES: Head can be turned 360° Replaceable head, nozzle outlets easily changed • Nozzle levels raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for extra strength, toughness, elasticity Operating thread only part to be lubricated • A modern barrel makes any Mathews Hydrant good as new • Low maintenance cost

MATHEWS HYDRANTS

***Made by* R. D. WOOD COMPANY**

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Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

LINK-BELT INSTALLATIONS ARE BUILT WITH *LINK-BELT MANUFACTURED COMPONENTS*

LINK-BELT MEANS *EVERYTHING* IN POWER TRANSMISSION AND CONVEYING

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In power transmission devices as in materials handling equipment, Link-Belt means a high standard of quality...a comprehensive line...nationwide service...responsibility for performance. Link-Belt chain drives, bearings, sprockets, speed reducers and speed changers use power *fully* by giving *positive, non-slip* transmission—dependable operation day after day under difficult conditions. In L-B installations there is no divided responsibility.

Link-Belt engineers are constantly cooperating with consulting, municipal and sanitary engineers to achieve positive results and highest efficiency.

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For positive power transmission at high or low speeds, coordinating rotation of numerous shafts. For short or long centers.

PROMAL CHAINS

Promal possesses all qualities desirable in a cast sprocket chain: toughness, strength, high yield point, high resistance to abrasive wear.

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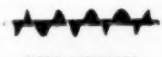
Bearings are sealed to keep grease in, dirt out. Sturdy, well-balanced rolls. Tough malleable iron brackets.



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For heavy duty service, made with split housings. Self-aligning, for fixed or floating shafts; press fit or adapter types.

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Used in Link-Belt Straightline Sludge Collectors. Prevent accumulation of sludge.

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If specific information is desired on any of the above items, contact our nearest branch office. Our Sanitary Engineering Division has a complete line of water, sewage or industrial liquid treatment equipment using the above component parts. This equipment consists of coarse and fine screens, grit and sludge collectors for grit chambers and settling tan. . scum breakers for sludge digestion tanks and sludge handling equipment. Write for catalogs.

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SCREENS · COLLECTORS · MIXERS · AERATORS

No Rubbing!

No Slamming!

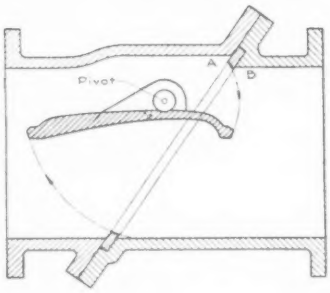
...just CUSHIONED CLOSING

WHEN IT'S A

CHAPMAN

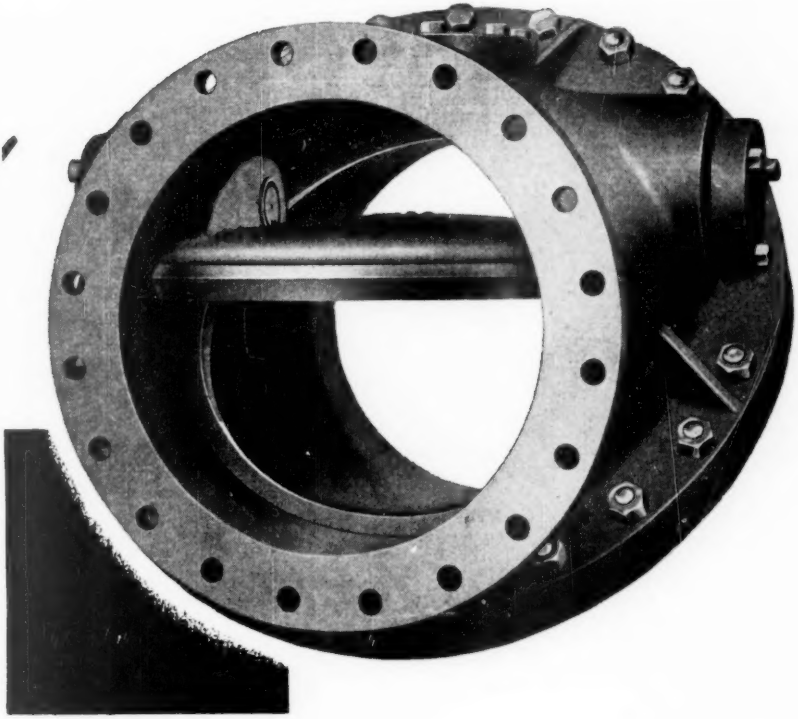
CHECK (TILTING DISC) VALVE

Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.



The Chapman Valve

INDIAN ORCHARD



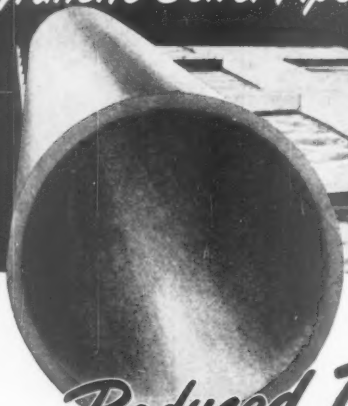
That's right! The balanced disc of a Chapman Tilting Disc Check Valve rides smoothly on the flow . . . lifts away easily when opening, closes quickly and quietly. There is no rubbing on the seat, no slamming . . . minimum wear on seats, hinge pins and bearings.

What's more, this design effects savings of from 65% to 80% in head losses over those experienced with conventional type check valves. And hammering and consequent strains on pipe lines are eliminated. Send today for your copy of the bulletin containing engineering data and reports of tests.

Manufacturing Company

MASSACHUSETTS

How to cut SEWAGE DISPOSAL COSTS with *Transite Sewer Pipe*



Reduced Treatment Costs

● Two features of Transite* Sewer Pipe present an opportunity for important savings in the treatment of sewage:

1. **Sleeve-type joints that make up tight and stay tight in service.**
2. **Long 13-foot lengths that mean fewer joints in the finished line.**

This double safeguard against infiltration—*tighter* joints as well as *fewer* joints—has the effect of cutting down on the load at the disposal plant . . . often to the extent that overall treatment costs are substantially reduced!

This reduction in sewage load also enables plant capacity to be conserved for future needs. And, where new treatment facilities are being planned, it permits consideration of a smaller treatment plant . . . with possible economies in both buildings and equipment.

Transite Offers Other Economies, Too. Other important savings are possible with this pipe because it has an exceptionally smooth interior which offers minimum resistance to the flow of sewage. Its flow capacity is unusually high—n=.010. This often makes possible the use of flatter grades and shallower trenches—with correspondingly lower excavation costs. Or, as an alternate economy, the use of smaller diameter pipe may be considered.

Low Maintenance Through the Years. Made of asbestos and cement combined into a homogeneous material of great stability, Transite Sewer Pipe is corrosion-resistant throughout. Tight joints safeguard against root trouble. And every Transite length is factory-tested for strength and uniformity. This adds up to low annual maintenance costs through the years.

For Further Information—If you are seeking ways to lower sewage disposal costs, you'll be interested in the many economies Transite Sewer Pipe can offer you. Send for free brochure containing further engineering data. Address Johns-Manville, Box 290, New York 16, N. Y.

*Reg. U. S. Pat. Off.

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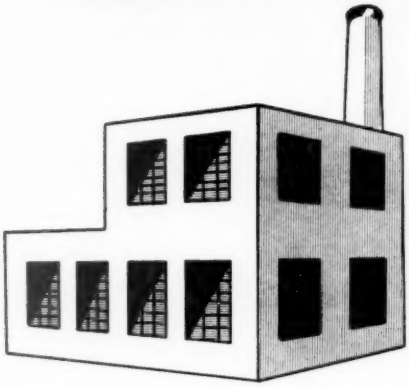
JM PRODUCTS

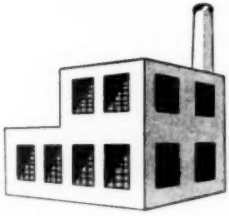
Transite Sewer Pipe

EXPERIENCE is a valuable asset



65%... NICHOLS installations

35%... installations by all other manufacturers



In the overall field of sewage sludge disposal by . . .
incineration to sterile ash,
heat drying for fertilizer and
combination drying or incineration . . .

it is worth remembering that 65% of the contracts awarded by municipalities have been to Nichols Engineering & Research Corporation.

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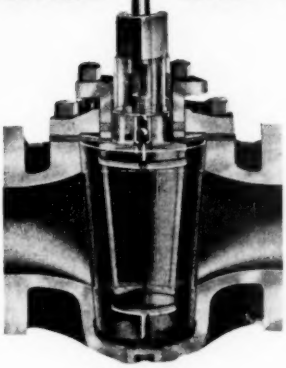

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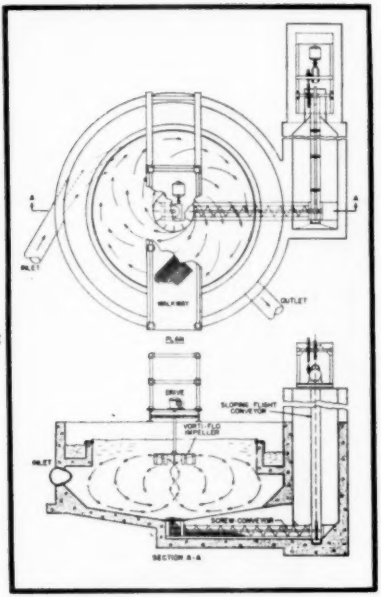

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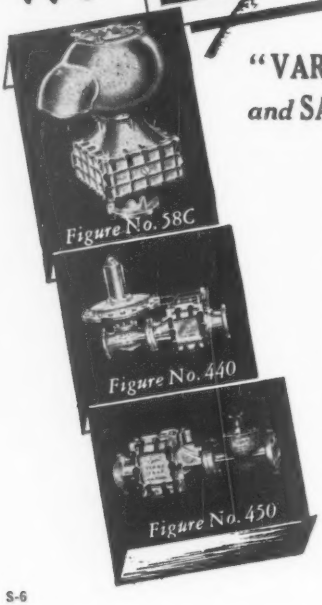

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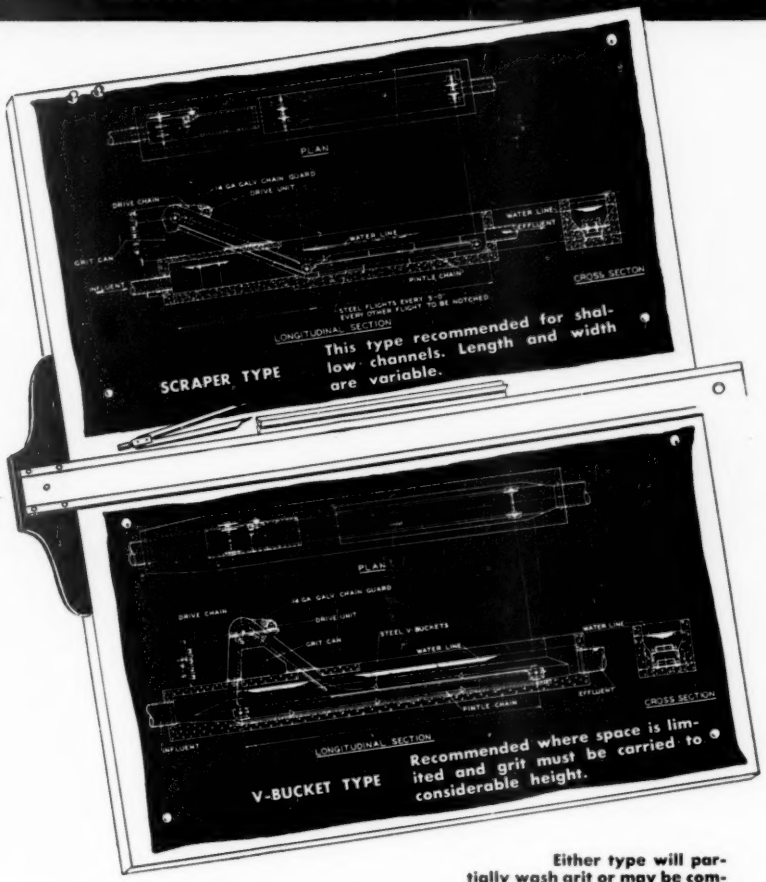

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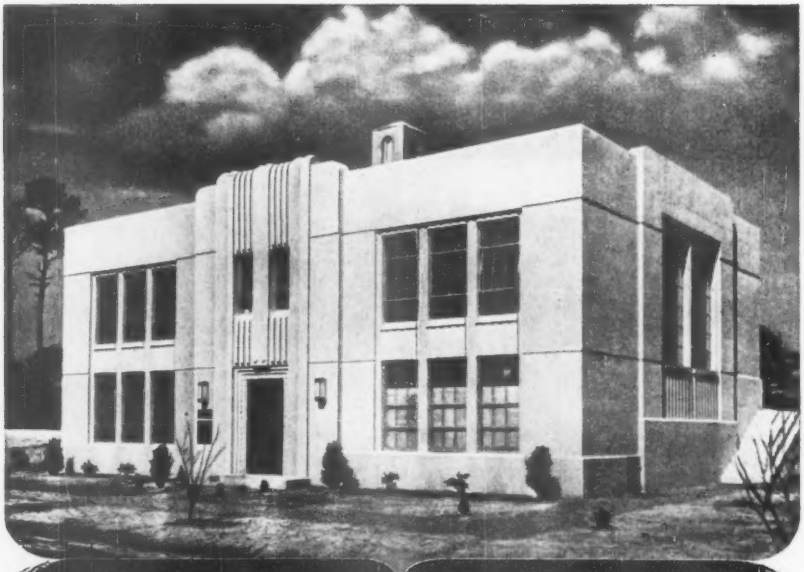

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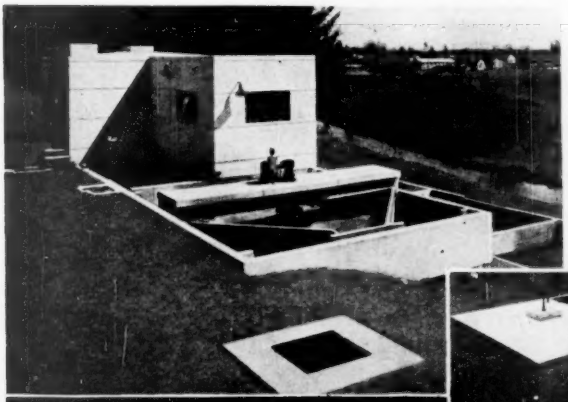

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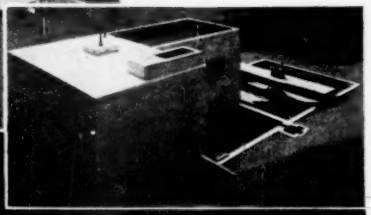

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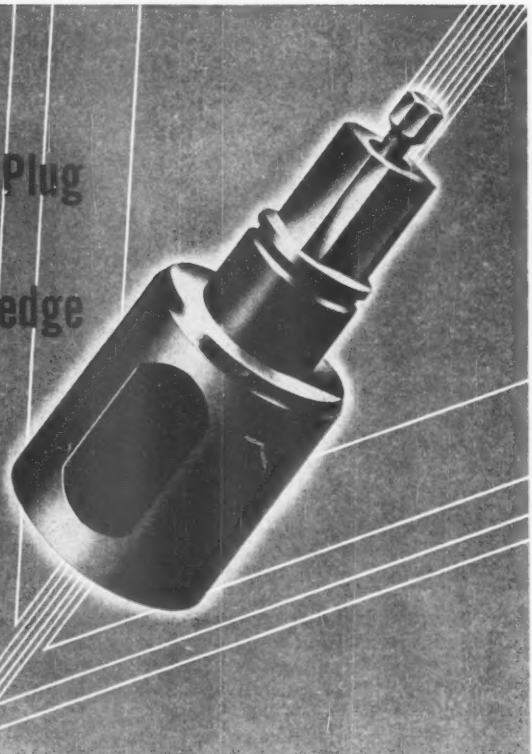

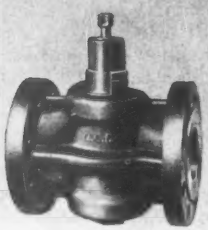

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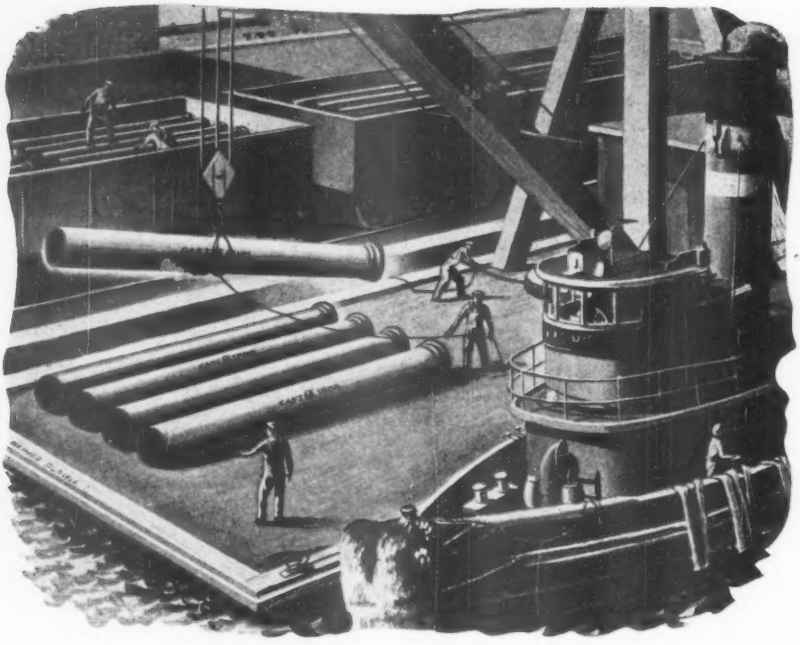

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SEWAGE WORKS JOURNAL

Official Bimonthly Publication — Federation of Sewage Works Associations

Volume XXI **JANUARY, 1949** **Number 1**

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Sewage Works

SUPPRESSION OF SEWER SLIMES

By C. W. Beardsley

Materials Testing Engineer, Dept. of Public Works, Bureau of Standards, Los Angeles, Calif.

Slime growths have been recognized as the principal causative agent for the production of sulfides in sewage. This paper reports an investigation that was undertaken to find means for the reduction or control of slimes in the Los Angeles sewer system. Features of the investigation were:

1. Studies of slime growths in sewers.
2. Development of apparatus for reproducing sewer conditions in this laboratory.
3. Growth of sewer slimes under controlled conditions.
4. Development of a test for the sulfate-reducing activity of slime.
5. Tests of the effect of disinfectants on slime.
6. Development of means for rendering surfaces inimical to slime growths.

Effect of Slimes on Sulfide Production

Fifteen years ago the writer investigated a small sewer line that produced hydrogen sulfide in excessive amount. It was observed that in small laterals only a few minutes away from the point of origin of the sewage, sulfide was already present in amounts of 3 to 4 p.p.m. The same sewage when stored in a clean jar did not generate measurable concentrations of sulfide for several hours. A conclusion was drawn that slimes on the sewer surfaces acted as zones of rapid biochemical change. The rate of transformation was apparently quite comparable to that produced by the zoogloeal organisms on the stones of a trickling filter.

Other investigators have made similar observations. Pomeroy and Bowlus in their outstanding studies of sulfide control (This Journal, **18**, 4, 597; July, 1946) formulated the following statement: "In free flowing sewers sulfides are produced only by slimes on the submerged surface of the sewer and by the deposited sludge. In the flowing body of the sewage, sulfides are not generated but, on the contrary, are destroyed by oxygen which is continually being absorbed from the surface. Even in completely filled sewers where oxygen absorption cannot occur, the amount of sulfide generation in the flowing sewage is generally negligible."

Effect of Slimes on Chlorine Demand

Suppression of sulfides is always desirable as a means of eliminating odor nuisances and corrosion. It has become especially desirable in the Los Angeles sewer system since the disinfection of the sewage by chlorination has been necessary. Sulfides exert a high and almost instantaneous chlorine demand. One sulfur atom, undergoing oxidation from the sulfide to the sulfate condition, destroys the bactericidal power of eight chlorine atoms. The chlorine atom is somewhat the heavier of the two and the ratio of equivalence by weight is nearly nine to one. It may be noted, however, that in alkaline solutions low concentrations of chlorine do not quantitatively

oxidize sulfides to sulfates. When the pH of the solution is 8.0 or higher the ratio of chlorine reduced to sulfide oxidized may fall as low as five to one.

In sewage the apparent ratio of equivalence is much higher. When sulfides are generated by the action of slimes, the ratio of increase in chlorine demand to the increase in total sulfides is likely to be 15 to 1 or higher. Ratios of 25 to 1 may occasionally be observed. The actual value in any particular case is determined by the character of the sewage and of the slime growth. In such cases the high chlorine demand is due to the production by the slime organisms of compounds containing reduced carbon and nitrogen. These substances, like the sulfides, exert a high and rapid chlorine demand.

Nature of Sewer Slimes

Sewer slime is an organic hodgepodge. Organisms of several classes and numerous species are present in every sample. As might be expected when so many living elements are involved, not all slime growths are alike. A gradation of characteristics may be observed where different types of organisms predominate, and seasonal variations occur in the biological makeup of slimes from any one location.

Differences in color, odor, texture, and consistency are apparent to a casual inspection. Colors range from black to white through shades of gray and tan. Various foul and earthy odors are encountered. Consistencies may be described as gelatinous, pasty, rubbery, stringy, fibrous or watery. In growth habits sewer slimes somewhat resemble algal slimes that form where thin films of water are flowing. They are, however, denser and more gelatinous than algal growths, and they have none of the green color characteristic of the algae.

Several classes of saprophytic microorganisms form slimy deposits when conditions are favorable. There are bacterial slimes and slimes derived from fungi. There is also a group of organisms known as slime molds (Myxomycetes) that have been variously classified as protozoa, fungi, and bacteria. All of these types are likely to be represented in the slimes of a large sewer system.

Living bacteria are always surrounded by a slimy capsule. Among certain species, slime formation by the outer membranes of the cell increases when conditions are favorable. Accelerated production of slime by masses of clustered bacteria leads to the formation of a bacterial gel. The bacteria continue to grow and multiply in a matrix of mucoid material. Normally motile species may temporarily acquire a sedentary habit. One of the most common of the slime-forming saprophytes in sewage is *Zoogloea ramigera*. Certain genera of sulfur bacteria, such as Thiopedia and Thiodictyon, likewise pass their entire existence in a covering of slime.

In the fungal classes of Phaecomycetes and Archimycetes are several species of slimy fungi that are normal inhabitants of sewers. One of the most common of these is *Leptomitus lacteus*. This fungus forms slimy grey sulfate-reducing masses in sewers and drains. Another species that is known to reduce sulfates is *Apodachlya brachynema*.

The Myxomycetes are mold-like slimy organisms that pass through a motile, amoeboid stage and eventually become stationary in moist locations where organic matter is present. The taxonomy and ecology of these organisms are somewhat obscure but they are indubitably present in sewer slimes.

Many protozoan forms, such as rotifers and *paramoecia* are found in the slime complex. These microscopic animals, composed of a single cell, move about actively in the surface layer. Slugs, nematodes, and small earthworms are attracted by the accumulation of organic material, and several

species of insects that characteristically deposit their eggs in moist places find the slime growth a suitable breeding ground. The larvae and pupae of these insects may be observed as one of the components of a slime deposit.

Bacteria, fungi, protozoa, worms, and insects all have their part in the chemical transformations brought about by the slime. The major changes, however, are induced by the bacteria. They have an enormous power to transform organic material because of their minute size, great numbers, and correspondingly great surface area. Bacteria are so small that they are practically all surface, and their numbers are so great that they constitute a substantial fraction of the total slime accumulation. The concept of clarification of liquids by substances of high specific surface is familiar to the chemist and engineer. Bacteria are living analogues of the activated clay and charcoal used in inorganic processes. But they are more than this; upon their surfaces are produced organic catalysts called enzymes, which have the power of initiating and controlling chemical reactions. Each one of these uncounted billions of microscopic organisms is a center of chemical activity, and in the aggregate the effect they produce is very great.

Methods of Investigation

In the compass of this article little can be said of the taxonomy and ecology of the slime organisms. Attention must be centered on the changes engendered by them in the sewage. Even in this limited field, over simplification is inevitable. The biochemical transformations involved are extremely complex, and general statements are likely to be subject to exceptions.

The identity of the slime organisms can most easily be determined when they are studied in pure cultures. Under the microscope mixed cultures from the sewer appear as masses of bacteria, protozoa, and larvae enclosed in a matrix of slimy material which is threaded with the hyphae of numerous fungi. The morphology of the component organisms is more or less obscured, and most of them can be certainly identified only in pure cultures.

A whole is more than the sum of its parts. Symbiotic relationships exist in mixed cultures which cannot be predicted from studies of isolated species. Transformations that occur in pure cultures are not reliable indices of what may be accomplished by diverse types of organisms in association. The effect of slime growths upon sewage is therefore best studied by observations and experiments upon mixed cultures taken directly from the sewer. The observations that follow have been derived from extensive studies of mixed cultures in sewers and in the laboratory.

Growth Habits

Slime formation begins when zoogloeal bacteria initiate deposits on the sewer walls. Minute islands of gelatinous material attach themselves at scattered points and begin to grow by accretion. Sewage colloids and suspended solids become entrapped in the slimy films, and free-swimming zoogloeal organisms join themselves to the growing deposit. Accretion continues until the scattered nuclei have merged into a continuous film.

The process of adhesion and growth by accretion can occur only where the water velocity is low. Where flow is rapid zoogloeal colonies are swept away before they attach themselves securely. The portion of the wetted channel most favorable to deposition is therefore the line where the surface of the flowing stream meets the wall. Longitudinal velocity here is negligible, and the slow rising and ebbing action induced by surface ripples favors deposition of suspended material from the stream. For this reason slime deposits begin where the stream surface contacts the wall of the chan-

nel, and because the stream level varies from time to time, they occur in a band between low and high water levels. Portions of the channel that are continuously submerged are often quite free from slime, and the deposits attain their greatest thickness at the most usual level of flow.

When the bacterial growths have become established, they are invaded by fungi which pierce them with the interlacing filaments of their hyphae. An incursion of mycophagous worms and insects follows the growth of the fungi. Rotifers, infusoria, and other microscopic animals join the developing complex. Hydrogen sulfide, appearing as a by-product of the metabolism of the bacteria, precipitates the ions of iron and other metals from the sewage. These precipitated sulfides become entrapped in the zoogloeal material and provide its characteristic black color. The presence of hydrogen sulfide also fosters the development of sulfur-oxidizing organisms. Presently the surface of the deposit is covered with a light colored film composed of *Beggiatoa alba* and similar species. The slime growth is now fully developed.

In autumn falling temperatures check the proliferation of the bacteria. Protozoa and slime-devouring higher organisms gain the ascendancy and extend their attacks until large areas have been denuded of slime. In Southern California this development becomes noticeable in February and March when the destruction of the underlying layer of reducing bacteria has deprived the filamentous oxidizing organisms of support. Ragged strips of the stringy surface layer hang by an attachment at one end from the sewer arch or cling to the sewer wall with one end floating free in the sewage stream. Such "stringers" and "floaters" are a familiar sight to maintenance crews.

Slime deposits grow most luxuriantly where air and water are continuously present. A splashing discharge from an influent channel induces slime proliferation on the surfaces wet by the spray. The maximum growth in a channel occurs at the level where fluctuations in flow alternately submerge the deposits and expose them to air. This characteristic leads to a daily cycle of sulfide production. The sulfide content of the sewage tends to rise and fall with the level of flow. At night when the water level in the channel drops to its lowest point, the area of submerged slime decreases to a minimum. The rate of transfer of sulfide from the slime to the flowing stream depends in part upon contact area, and consequently declines to a corresponding minimum. Dissolved sulfides and chlorine demand tend therefore to be lowest when the flow is least.

The chemical transformations that take place in the slime deposit are varied and complex. Carbon, nitrogen, and sulfur are oxidized and reduced. Some of the changes are carried through several stages by the cooperative action of different species of organisms. Nitrates are reduced to amines by reducing bacteria while contiguous oxidizing types convert ammonia to nitrates. Dissolved sulfates are reduced by saprophytic bacteria, step by step, to hydrogen sulfide, while sulfur bacteria drive the same reactions in the opposite direction. The maze of chemical action and reaction is carried on by enzymes, most of which are of bacterial origin.

Just as in a current of air there is a rapid motion of the molecules in all possible directions, but a net drift of the air mass in one direction; so, in a slime deposit both reduction and oxidation occur, but a net reaction develops in one direction. The growth of reducing slimes is favored by warm weather. These sulfide-producing deposits appear generally as a black ooze or gel, lacking the filamentous structure characteristic of other types.

Sewage in contact with such growths becomes charged with sulfides.

The rate of sulfide output is controlled by several factors. Temperature exerts an important influence. Every type of microorganism has an optimum temperature at which its life processes proceed at a maximum rate. The optimum is always a normal temperature of the usual environment of the species. For *E. coli* the optimum is the temperature of the human body. Many of the saprophytes whose normal habitat is the soil or the surface waters of the earth proliferate most rapidly at about 80° F. The 80° F. optimum applies to the sulfate-reducing organism in sewer slimes. Above and below this temperature the output of sulfide decreases.

In Southern California black slimes tend to disappear from the smaller sewers in the winter months and to be replaced by lighter colored growths that produce no sulfide. The succession is probably induced by drainage of cold air into the sewer on nights when temperatures fall below 40° F. In trunk lines sewers the presence of a large stream of relatively warm water serves to moderate temperatures on cooler nights and black slimes persist throughout the year.

Another important factor is the availability of nutrient material. The strength of the sewage, as measured by B.O.D., is one measure of availability. Concentration of nutriment, however, is not the whole story. Bacteria, like humans, respond to quality in their food. Some nutrients are better suited to their assimilative processes than others. Slime-forming organisms thrive on soluble carbohydrates. Sugars can readily be transformed into the polysaccharide material that composes their zoogloeal envelope. For this reason the waste from a brewery or food-processing establishment may stimulate the formation of slime, and a sulfide problem may result even when the B.O.D. of the plant effluent is not unduly high. The present trend toward garbage disposal into the sewer by the use of grinders is certain to make the control of sulfides in sewage more difficult.

The biological composition of the slime complex is a third factor that affects the rate of sulfide production. The balance between bacteria and fungi, protozoa and metazoa fluctuates in ever-changing phases. Bacteria concerned with transformations of nitrogen are abundant in some deposits, and the numerical ratio of sulfur-reducing organisms to other types is by no means constant. Oxidizing types tend to predominate in the winter, while sulfur-reducing types flourish when sewage temperatures approach 80° F.

Occasionally it has been observed that a sewer that has been trouble-free for a number of years suddenly produces sulfide at an abnormal rate. After a year or two such a sewer may revert to its original state. Such epidemics of sulfide production cannot be attributed to changes of temperature or turbulence. Attempts to correlate them with changes of sewage strength have been unsatisfactory. It seems probable that such sewers become temporarily infested with exceptionally active strains of sulfur reducers, and that after a period of dominance, these organisms give way to other types.

The age and condition of a slime growth has a marked influence upon sulfide output. Bacteria are more prone to change and mutation than higher life forms. The cells in young cultures are often quite different from the cells in the same cultures a few hours later. Degeneration may be induced by unfavorable temperatures and nutrients, or by other adverse conditions. Occasionally changes of form and function occur that appear unrelated to environment. The enzymatic constitution of the species may undergo changes that accentuate or destroy the ability to bring about cer-

tain chemical reactions. A strain of bacteria in a few days may pass through changes of morphology and physiology more profound than would be experienced by higher life forms in a geological epoch.

Sulfide Generating Activity

Variation of slimes with respect to output of sulfide became apparent early in the investigation. Some slimes that could not be distinguished from active types by visual inspection produced no measurable concentration of sulfide at all. Many others generated only at a sluggish rate. An occasional deposit was found, however, of such activity that any nutrient medium in which it was placed became saturated with sulfide in a few hours.

The capacity to generate sulfides was the characteristic of slimes of most concern in this study. A technic was therefore developed for evaluating that characteristic. To facilitate comparison the degree of sulfide generating activity was expressed by a number called the Sulfide Activity Index.

The test for sulfide activity is made by spreading 5.0 gm. of the slime upon an 11-cm. diameter filter paper. The paper is then immersed in a liter of sterile nutrient solution and incubated at 80° F. The total sulfide content of the nutrient solution in parts per million after 18 hours is taken as the sulfide activity index of the slime.

The nutrient solution is made by dissolving 0.300 gm. of dextrose, 0.300 gm. of dehydated peptone (Difco); 0.300 gm. of dehydated nutrient broth (Difco), and 0.100 gm. of sodium sulfate in 1 liter of distilled water.

Growth of Laboratory Cultures

The extent and character of the slime deposit at any sewer location varies irregularly from month to month. Changes are observed that cannot be traced to their causes. It became apparent that little progress would be made in evaluating the factors that promote or inhibit the development of slimes unless the growths were brought into the laboratory and subjected to controlled conditions. Bottle tests would be necessary.

Every student of the changes that occur in sewage recognizes the limitations of bottle tests and deplores the necessity of resorting to them. The condition of sewage at any instant is a resultant of physical, chemical and biological factors that change from moment to moment. The sewer functions, not only as a conveyor of sewage from its origin to its ultimate dilution, but as an aeration and digestion unit in which the character of the sewage is modified.

In a static bottle bacterial development takes a different course than in the sewer. The proliferation of bacteria is conditioned by their environment, and changes of environment may lead to undue multiplication or complete destruction of certain types. Among the factors that affect the microorganisms in a sewer, none is more critically important than the oxygen supply. Abundance or lack of oxygen determines to a large degree what shall be the predominant species of bacteria, the prevailing biochemical reactions and the final degradation products.

The solubility of oxygen in water is about 8 p.p.m. This is only a small fraction of the normal oxygen demand of sewage. The oxygen in sewage, therefore, becomes rapidly depleted unless it is renewed by absorption of fresh supplies from the surface. In a free-flowing sewer, absorption of oxygen at the surface takes place at a rate that accelerates in proportion to oxygen depletion. The turbulence resulting from flow mixes the oxygen-rich surface films with the oxygen-poor lower layers, so that a balance between absorption and depletion occurs before the oxygen supply is exhausted. A static bottle, lacking the distribution of

oxygen by mixing and convection, develops zones of anaerobic activity.

Since bottle tests were desirable in order to obtain adequate controls, it was decided to substitute for the usual static bottle, a rocking bottle in which absorption and convection would occur as in a sewer. An apparatus was built (Figure 1) which consisted essentially

FIGURE 1.—Rocking incubator for testing action of disinfectants on slimes.

of a frame holding four bottles that were rocked continuously by a motor. The angle and the rate of rocking were variable over a wide range so that the turbulence of either a sluggish or a fast-flowing sewer could be approximated. The apparatus was enclosed in a case provided with heaters, ventilators, and thermostat for temperature control. Most of the tests were carried out at 80° F., which is an approximate summer maximum for Los Angeles.

Obtaining satisfactory growths of sewer slimes in bottles proved more difficult than had been anticipated. In order to provide a suitable surface for the attachment of the bacterial gel, the interior of the bottle was coated with cement mortar. The bottles were filled with sewage and sewer slimes and then were kept in continuous motion. The zoogloeal organisms refused to attach themselves to the bottle. They would readily adhere to wood or fiber surfaces placed in the bottle, but not to the bottle itself. It appeared probable that some slightly soluble constituent of the cement mortar was antagonistic to the bacteria. The bottles were washed repeatedly with hot water and dilute acid in an effort to overcome the antagonism. After about 2 weeks the slime-repelling factor in the mortar disappeared and deposits apparently identical with the slimes found in sewers spread over the interior surfaces of the bottles.

After the first slime growth had been obtained, there was never again any difficulty in getting fresh slime cultures to grow in the bottles. Periodically they were cleaned out and sterilized by baking. When fresh slimes from the sewer with fresh sewage as a nutrient were placed in the bottles and kept in motion, the slime organisms would readily attach themselves to the mortar. The difficulty experienced in obtaining the first slime growths and the ease with which subsequent cultures were grown furnished a clue to a method of dealing with the slime problem.

Most of the phenomena of slime growth and activity are exhibited by the laboratory cultures. The tendency to variability in the rate of sulfide production is readily demonstrated. When a new culture is given a favorable environment, the output of sulfide may be observed to increase, slowly at first, and then at an accelerating rate. A high output of sulfide may be obtained which will persist for a long

time. Eventually a decline sets in and the generation of sulfide falls to a lower rate.

The reasons for the decline are obscure. When the culture is actively proliferating, a short exposure to unfavorable conditions scarcely checks the generation of sulfide. When a decline has set in, unfavorable conditions bring sulfide production to a standstill. A high rate of production is not readily restored to a decadent culture, but prolonged exposure to optimum temperatures and nutrients may bring on another period of high activity. The periods of proliferation and decline appear to be primarily associated with life cycles of the organisms, and only secondarily with immediate environment. When an attempt is made to evaluate the response of slime organisms to environmental changes, the time lag that may occur in certain developmental phases must be considered.

Tests of Disinfectants

At first it was hoped that slimes might be inhibited or destroyed by the addition of bactericides to the sewage. In exploration of this possibility a considerable number of disinfectants were tested by the following general method. Similar slime cultures were grown in all four bottles. In spite of efforts to secure uniformity, it was never possible to obtain four cultures that produced sulfide at precisely the same rate. Differences in activity would develop, so that completely satisfactory controls for experiments with disinfectants were never available. A bottle that generated sulfide at an approximate mean rate for the group was selected as a control and reserved without treatment. Ten parts per million of the disinfectant under test were added to one of the remaining bottles, 20 p.p.m. were added to a second, and 30 p.p.m. to a third. Concentrations greater than 30 p.p.m. were not tested since they were deemed too costly for use in sewers.

The rocking mechanism was adjusted to permit a moderate build-up of sulfide in the control bottle. Any marked reduction in the rate of sulfide production by the bactericide in the other bottles was thus readily observed. Slight bacteriostatic effects could not be evaluated. This, however, was not regarded as important; only bactericides showing a decisive action in the bottles would have been considered for further testing in the sewer.

Bactericides that are inexpensive enough to be used for sewage disinfection fall into three general classes: (1) metallic ions; (2) halogen substituted organic compounds; (3) halogens and halogenated amines. Many bactericides and bacteriostats of other types are useful for clinical work, but are too costly for mass disinfection.

Metallic ions, particularly the cupric ion, had a considerable vogue for sewage disinfection about the turn of the century. They were abandoned, except for special uses, when the superiority of chlorine became evident. Metallic ions do not destroy bacteria efficiently. Their action tends to be bacteriostatic rather than bactericidal. The ions that form complexes with ammonia are most effective, and among these the cupric, mercuric and silver ions are outstanding. It appears probable that the tendency of these ions to associate themselves with ammonia enables them to concentrate upon the numerous amine groups that are present in the bacterial enzymes, causing temporary but not irreversible inactivation. Copper, mercury and silver produce noticeable bacteriostasis in very great dilution. For most bacterial species the lethal concentration is hundreds of times greater than the amount required for bacteriostatic action.

The following metallic ions were tested for their effect upon slime: Cu^{++}, Cu^{+}, Zn^{++}, Hg^{++}, Cd^{++}, Co^{+++}, Ni^{+++},

Fe^{+++}, Fe^{++}, and Cr^{+++}. None of these showed evidence of lethal action against slime organisms when used in economically practicable amounts. Copper, mercury, and zinc ions produce a temporary check in sulfide build-up by precipitating sulfides out of solution. This effect is only temporary because the ions are progressively removed from the field of action. If, after treatment with these ions, the slime cultures are again supplied with fresh non-toxic sewage, sulfide generation is resumed at approximately the original rate.

In Table I are shown values for the reduction of the activity of slimes by various metallic ions. The indication of the tests represented in this table is that none of these ions could be used economically to suppress the generation of sulfide by sewer slimes. These values apply only to the slime growths tested. Other growths in other developmental phases or under different conditions may be expected to respond differently. A very extensive program of testing would be necessary to fully explore the possibilities of each ion.

TABLE I.—Reduction of Sulfide Activity Index of Slime Growths After Six Hours Exposure to Various Ions

Ion	Reduction of Index for Indicated Dosage		
	10 p.p.m.	20 p.p.m.	30 p.p.m.
Cu^{++}	10	20	45
Cu^{+}	0	10	20
Zn^{++}	25	20	35
Hg^{++}	25	40	45
Cd^{++}	5	10	15
Co^{+++}	0	0	10
Ni^{+++}	—	—	5
Fe^{+++}	—	—	0
Fe^{++}	—	—	0

The phenols and cresols are among the most effective of the organic disinfectants. The bactericidal efficiency of these compounds is enhanced by substitution on the ring of side structures containing long aliphatic chains or aromatic nuclei. Halogen substitution also effectively increases germicidal potency. In such substitution products increasing lethal power is accompanied by decreasing water solubility. Emulsification is necessary before they can be used as disinfectants in sewage. Emulsification, however, is not a disadvantage. When disinfectants must be used in low concentration, emulsions are often more effective than solutions. The bactericidal power of the oily enclosed phase is not destroyed by attenuation as dilution is increased. The droplets of disinfectant, although they are separated by increasing amounts of the enclosing medium, remain in sufficient concentration for lethal effect wherever a bacterium is encountered.

Emulsions of the chloro and bromo derivatives of benzene, aniline, and phenol, and emulsions of chloroform and carbon tetrachloride, were tested in concentrations of 30 p.p.m. Except in the case of the chlorobenzenes the period of contact was limited to 6 hours. An emulsion of dichlorobenzene (Cloroben) was tested with 4 days of continuous contact. No significant diminution of sulfide-generating activity was apparent in any test.

Quaternary ammonium compounds dissolve readily in water and they possess remarkable bactericidal powers. Some compounds of this group have been found germicidal to *Staphylococcus aureus* in concentrations of 20 p.p.m. or less. Their fields of application and their limitations have not been fully explored, but it is probable they will never prove useful against sewage organisms. Their cost is high and they are inactivated by soaps which are often present in sewage. One quarternary ammonium compound, trimethyl lauryl ammonium chloride, was tested for action against sewer slime and found to be completely ineffective.

One serious defect of organic disinfectants for use in sewage is a tendency to specific action. Certain groups of organisms are affected while others remain immune. Methyl violet inhibits the growth of staphylococci in dilutions of less than 1 p.p.m. If it were equally effective toward all bacteria, high cost might not bar its use in sewage. Its action is specific to certain organisms, however. About 150 times as much is required to inhibit gram-negative *E. coli* as is necessary for the gram-positive staphylococcus. In clinical work and bacteriological studies specificity is often an advantage, but for sewage a universal disinfectant is needed.

There is some possibility that some of the compounds of carbon might have appeared more promising if contact with the slime had been extended to a longer period. The concentrations tested, however, were much greater than the dose that would be economically feasible in large sewers. It appears probable that any disinfectant that would succeed in a lower concentration over a longer period, would have shown some effect in 6 hours at the concentration used.

Most of the organic disinfectants require concentrations of 500 to 10,000 p.p.m. for lethal action on bacteria in suspension in water. Greater concentrations are required for effective action against slimes. The cost of such chemicals ranges upward from 25¢ per pound. It appears that the tonnages that would be necessary for use in sewer systems would prove prohibitively expensive.

Chlorine has been recognized as the practical disinfectant for sewage treatment. Its low cost, universal action, and effectiveness in great dilution give it a unique place in this field. Most of the freely suspended sewage organisms are destroyed by a chlorine residual of 1 p.p.m. In high concentrations of organic matter, such as sewage solids or slime deposits, the bactericidal effectiveness of chlorine is reduced.

A series of tests was undertaken to determine what chlorine residual would, in the general case, be required to inactivate a slime growth with respect to the generation of sulfide. It was recognized that the resistance of various kinds of slimes to the lethal action of chlorine might be different. It was hoped, however, that some information about the concentration of chlorine most frequently necessary for the destruction of slime might be obtained.

Slime growths from various sewers were exposed to chlorinated sewage containing concentrations of residual chlorine ranging up to 50 p.p.m. The disinfection time was varied from 2 to 24 hours. Some growths were inactivated by chlorine residuals of 10 to 15 p.p.m. maintained for 2 hours. Such slimes lost their black color and acquired a whitish or bleached-out appearance. When washed free of disinfectant and supplied with fresh sewage they no longer produced sulfides. Other growths proved more resistant. For many of the slimes that were tested the lethal dose was about 50 p.p.m. Lesser concentrations of chlorine reduced their activity but did not destroy it.

Figure 2 represents the outcome of one series of experiments. In this series the slime organisms were exposed to the toxic action of chlorine for 2 hours. Two grams of fresh slime were spread upon a filter paper and immersed in sewage which contained a 2-hour residual of chlorine in the amount shown. After 2 hours of contact the slimes were transferred to fresh sewage and incubated at 80° F. for 18 hours. The reduction of sulfide-generating activity was determined as the percentage decrease in sulfide production with respect to a control sample that had not been in contact with chlorine.

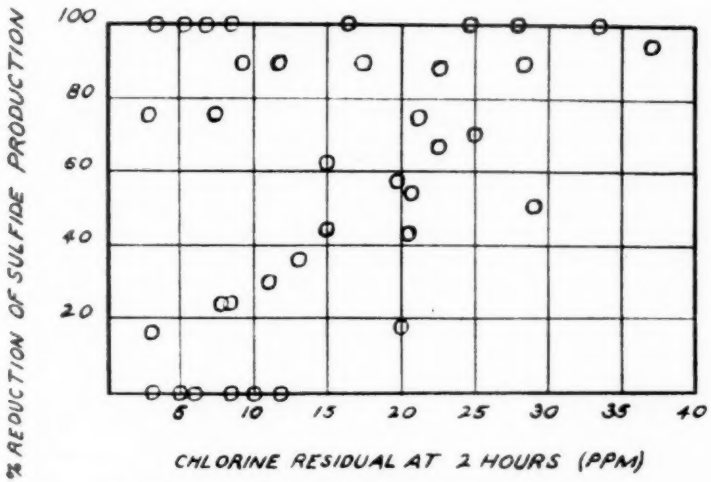

FIGURE 2.—Effect of chlorine on sulfide production.

A measure of insight into the problem of slime suppression may be derived from a study of this figure. Non-uniformity of disinfection is the outstanding characteristic. The relation between chlorine concentration and the reduction of sulfide production can be better represented by an area than a line. When moderate concentrations of chlorine are used either stimulation or complete inactivation may occur. The deciding factor appears to be the makeup and condition of the slime complex. When chlorine residuals of about 20 p.p.m. are employed a decrease in sulfide generating activity is usually apparent, but in most cases the slime organisms are not killed. Recovery is rapid when treatment with chlorine is discontinued. The drop in sulfide production is followed by a rebound to a high output in the course of 3 or 4 days.

It appears unlikely that the elimination of sewer slimes by disinfectants added to the sewage can ever prove an economically satisfactory procedure. High concentrations of organic matter, such as are found in slime deposits, impair the effectiveness of toxic agents. Slime is produced by heavily capsulated bacteria as a defense against unfavorable environments, and the resistance of slime organisms to attack by disinfectants is great.

Tests of Surface Treatments

It is often said that an ounce of prevention is worth a ton of cure. This idea, applied to the slime problem, suggests that it may be easier to prevent a slime growth from starting than to inhibit its activity when it has become established. The difficulty experienced in obtaining slime cultures on fresh cement mortar indicated that traces of antagonistic substances might be sufficient to suppress the formation of slime. A toxic substance of low solubility and volatility, when applied to a surface, might confer immunity to slime for a long period.

Exploration of this approach to the slime problem began in October, 1946. The compounds selected for test were the isomeric dichlorobenzenes. These bactericidal compounds are insoluble in water and relatively non-volatile. The common use of paradichlorobenzene as a moth repellent and wood

preservative is based on these properties.

One of these experiments involved the application of dichlorobenzene to an existing sewer. A manhole was selected for the test in which two lines came together to a common outlet. At the beginning of the test both lines had similar slime growths of about ¼ in. thickness. Both branches were cleaned and all traces of the bacterial film were removed with a wire brush. The north branch was then disinfected with a 10 per cent emulsion of orthodichlorobenzene (Cloroben), while the south branch was reserved untreated as a control.

This test indicated that slime formation could be strongly inhibited by a surface treatment. The south branch, which was cleansed but not treated, remained free from slime less than 30 days. New and heavier slime growths were present at the next inspection, and the sulfide activity index of the new growth was higher than the old.

FIGURE 3.—Testing surface treatments for inhibition of slime growth.

The net effect of cleaning had been to substitute for a decadent growth a younger and more vigorous development. The north branch, which was disinfected after cleaning, has remained free from slime for more than a year. The traces of bacterial film that have reappeared are apparently composed of oxidizing types only. When tested for sulfide generating activity, they consistently show an index of zero. The production of sulfide has been completely suppressed.

It is probable that this experiment does not represent the ultimate that can be achieved by surface treatment. The sewer had been in service many years when the test was made. The dichlorobenzene was applied to a surface that was saturated with water. There was, therefore, little opportunity for the oily disinfectant to enter the pores of the surface or to gain satisfactory adhesion. Treatments applied to the dry surface of a new sewer might reasonably be expected to prove more effective and more permanent.

Further tests of this general character are in progress at the present time. It is too early, however, to gauge the long range effectiveness of such treatments. Conclusions cannot be based on the presence or absence of sulfide-producing slimes in the winter and spring months. At these seasons the occurrence of such growths in large sewers appears to be more or less accidental, and in smaller channels they are almost non-existent. Only in late summer is it possible reasonably to ascribe the absence of sulfide-producing slimes to the influence of the antibacterial agent.

In order to obtain conditions that could be controlled for the intensive study of surface treatments, a special incubator for the culture of slimes was devised. Slime formation in the sewer proceeds most rapidly on surfaces that are subject to periodic inundation. A special apparatus (Figure 3) was constructed to reproduce

this condition. In this device test plaques are subjected to slow periodic immersion and re-emergence into the air. Sewage inoculated with slime organisms serves as an immersion medium. The temperature is thermostatically maintained at 80° F. Under these conditions slime formation on the test plaques begins immediately unless they are antagonistc to bacterial growth.

The surface treatments selected for testing were applied to plaques which had been molded of ceramic clay and burned in a muffle to produce surfaces similar to clay sewer pipes. Each plaque was impregnated with an antibacterial chemical at one end. The other end was reserved untreated as a control. After treatment the plaques were washed to remove excess reagents that had not been firmly adsorbed on the surface.

A report cannot be made on these experiments at the present time. The relation between chemical structure and bacteriostatic action is obscure and the test data are often involved in paradox and apparent contradiction. Different bacterial species have varying susceptibilities to toxic agents. When studies are confined to a single species unpredictable variation still confounds the investigator. Strains endowed with high specific resistance suddenly appear to set at naught findings that had been considered assured. In the case of sewer slimes which contain an unknown number of different species and classes of organisms, the relation between chemical constitution and lethal action is far more difficult to trace. The isolation of significant and general truth from findings that are only incidentally and occasionally true will require long and careful study.

It appears that the suppression of slime growth in sewers will in most cases be economically impracticable. The insistent drive of living organisms to invade all suitable environments is behind slime growth. Probably suppression is not always desirable. When sewers have sufficient grade to provide for rapid flow, and when the temperature of the sewage is 70° F. or less, a policy of laissez faire may be adopted with reference to slimes. Under these conditions their activity may even be beneficial. They have the self-regulating characteristic that nature gives to most of her creations and they start the sewage on the road to stability. Only when temperatures are high and velocities are low do they become a destructive nuisance.

Summary

The slimes that form on the walls of sewers are diverse in character. Their effect on the sewage is variable with respect to time and place. It appears unlikely that they can be suppressed or eliminated by chemical treatments added to the sewage because of their high resistance to disinfectants.

Some types of sulfate producing slimes can apparently be inhibited by chemical treatments of sewer surfaces. Antibacterial substances applied to sewer pipe inhibited the production of sulfide for more than a year. Such treatments exhibit the phenomenon of specificity. Certain types of organisms are suppressed while others are unaffected. Further investigation will be required to evaluate the economic advantages of surface treatment.

PHOTOELECTRIC ESTIMATION OF SUSPENDED SOLIDS IN SEWAGE[1]

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Preliminary studies in 1945 established the need of processing sewage particles to a more uniform size distribution in order to obtain satisfactory correlation between the transmission of light and the weight of total suspended solids by the standard Gooch test. In these studies a 100- to 200-ml. sample was homogenized by a hand operated homogenizer. Although the correlation was satisfactory, the homogenization was tedious and the size of sample inadequately small for a representative sample, particularly on raw sewage.

A Waring Blendor was procured in 1947 for the homogenization of sewage samples. A sample of 800 ml., or the entire contents of a 24-hour composite bottle, could be homogenized at one time. With the use of the Waring Blendor and a Photo Volt Model 402E Lumetron, calibration charts were established for the satisfactory photoestimation of suspended solids. It is the purpose of this paper to record the findings.

Apparatus

The photelometer used in these studies was a Photo Volt Model 402E Lumetron. This instrument is distinct from most photoelectric instruments in that the cuvette compartment is adaptable to a variety of vessels, ranging from a test tube in upright position with a horizontal light path to a large cylindrical cuvette with closed ends which provide a light path of 150 mm. through the sample for very low turbidity readings. A 15-ml. rectangular cuvette with parallel clear glass walls and a light path of 20 mm. was selected for use. The cuvette was placed in the compartment 145 to 165 mm. distant from the photo cell. The distant location of the cuvette increased the loss of light scattered by particles and thus magnified turbidity measurement in contrast to color absorption.

A 420M light filter was selected as most suitable and gave a desirable working range. The photometer is equipped with a sensitive desk galvanometer and a potentiometer having a scale reading divided into 100 parts. With no light sensitizing the photo cell, a null point or zero deflection of the galvanometer corresponds to a reading of 0.0 to 1.2 on the potentiometer, while a scale reading of 100 can be adjusted by a variable shutter arrangement.

At the beginning of a set of readings the instrument was adjusted to give a transmission of 100 scale units with a clean (20-mm. light path) cuvette filled with distilled water and placed in the sample compartment 145 to 165 mm. from the photo-cell. During a set of readings, a sample of distilled water was tested to check on the instrument characteristics and the cleanliness of the cuvette walls.

The Waring Blendor consists of a 1 quart capacity, tapered heavy wall glass vessel of irregular perimeter with a four-blade impeller actuated by a high speed motor.

[1] Presented at 112th Annual Meeting, American Chemical Society, 1947, New York City.

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Standardization of Period of Homogenization

Initial tests on the proper length of processing samples in the blendor were determined for raw sewage and aeration tank liquors. Ten 250-ml. samples of aeration tank liquor collected on four different days and from four different aerators were homogenized for a total of 0.25, 0.5, 1.0 and 2.0 minutes. After each treatment a subsample (20 ml.) was diluted to yield a suspended solids concentration of 75 to 100 p.p.m. and tested by the photometer. This dilution was further diluted 1:1 to give a suspended solids concentration of 35 to 50 p.p.m. The resulting transmission readings are presented in Table I.

The table indicates that during the first 15 sec. of blending there is a large decrease in the light transmission. Continued blending for two or more minutes decreases the light transmission at a slow rate.

Six samples of raw sewage were similarly blended for a total of 0, 0.25, 0.5, 1.0, and 2.0 min. and two dilutions of each were tested in the photometer. The results in Table II show the light transmission scale readings and the ratio of scale reading for a particular blending period to that obtained after 0.5 min. of blending. Just as in the case of aerator liquors, the change in transmission due to increased blending is greater for high concentrations of suspended solids or lower transmission values.

The ratios of photometer reading for a particular period of blending to the photometer reading after 0.5 min. blending is presented in Figure 1. The results show that a major decrease in the transmission occurs during the first 15 sec. of blending and a much slower decrease continues thereafter for at least 2 minutes. The greater the suspended solids content of the dilution tested, the greater the relative

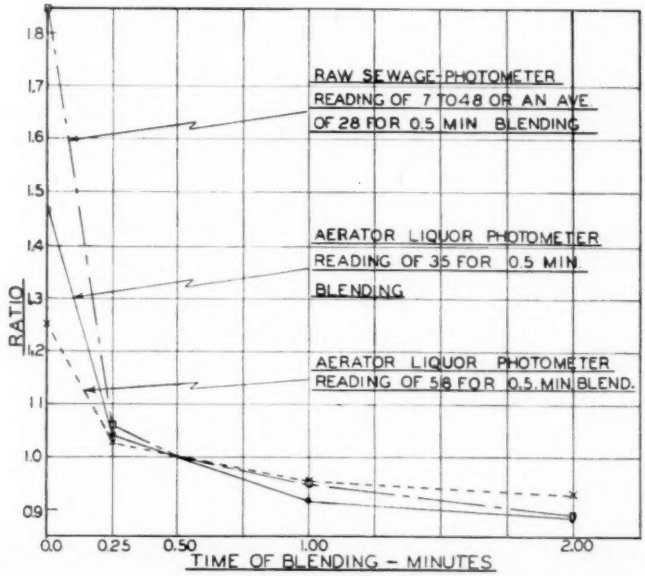

FIGURE 1.—The effect of time of blending on the photometer transmission expressed as a ratio of scale readings to the scale reading of samples blended for 0.5 minutes.

TABLE I.—Photometer Tests on Aeration Tank Liquor Blended 0 to 2 Minutes

Sample	Dilution of Homog. Sample	Susp. Solids in Dil. (p.p.m.)	Percentage Transmission for Blending Periods in Minutes				
			0	0.25	0.5	1.0	2.0
1	1:15	74.6	51.2	38.9	36.6	34.4	31.7
2	1:15	73.3	54.6	39.5	38.6	34.5	33.0
3	1:20	70.0	51.0	39.2	37.4	34.9	33.1
4	1:15	93.3	53.0	39.4	38.0	35.0	32.3
5	1:18	100.0	50.6	34.5	33.4	31.6	29.5
6	1:16	106.2	50.1	31.2	30.9	28.6	27.2
7	1:13	115.4	50.7	35.2	33.5	30.0	28.1
8	1:16	100.0	50.6	38.2	36.1	34.6	32.0
9	1:16	106.2	55.0	36.4	34.5	31.1	30.5
10	1:14	100.0	51.6	34.2	33.0	30.0	28.9
Average	—	93.9	52.0	36.7	35.3	32.5	30.7
1	1:30	37.3	66.0	61.5	59.5	57.4	54.6
2	1:30	36.7	71.5	61.5	61.0	58.2	54.6
3	1:40	35.0	73.0	60.6	60.0	56.6	55.2
4a	1:18	49.0	70.3	59.6	55.2	51.9	49.3
5	1:36	50.0	72.6	59.1	56.4	56.1	55.6
6	1:32	53.1	70.6	57.0	53.6	51.9	51.3
7	1:26	57.7	73.1	59.5	58.2	54.0	52.9
8	1:32	50.0	73.4	60.6	59.0	57.4	56.0
9	1:32	53.1	74.4	59.1	57.2	55.2	53.6
10	1:28	50.0	77.2	58.4	56.2	54.2	52.5
Average	—	47.2	72.3	59.6	57.6	54.2	53.5

TABLE II.—Photometer Tests on Raw Sewage Homogenized 0 to 2 Minutes

Sample	Percentage Transmission for Blending Periods in Minutes					Ratio of Indicated Transmission to Transmission After 30 Seconds Blending				
	0	0.25	0.5	1.0	2.0	0	0.25	0.5	1.0	2.0
1	18.2	7.9	7.4	7.1	6.5	2.46	1.07	1.00	0.96	0.88
2	30.3	13.2	11.4	10.8	9.9	2.66	1.16	1.00	0.95	0.87
3	35.5	16.5	14.1	13.0	10.2	2.52	1.17	1.00	0.92	0.72
4	40.4	25.4	23.5	23.2	21.7	1.72	1.08	1.00	0.99	0.92
5	40.7	22.3	22.4	21.6	21.0	1.82	1.00	1.00	0.96	0.94
6	41.3	22.3	21.9	20.6	18.2	1.88	1.02	1.00	0.94	0.83
7	41.8	26.0	24.2	22.6	22.0	1.73	1.07	1.00	0.93	0.91
8	52.2	35.0	30.8	29.7	28.8	1.79	1.13	1.00	0.96	0.93
9	60.3	40.4	37.7	34.1	30.2	1.60	1.08	1.00	0.90	0.80
10	63.0	50.1	47.7	47.4	45.8	1.32	1.05	1.00	0.99	0.96
11	63.2	46.3	45.6	42.8	39.2	1.38	1.01	1.00	0.94	0.86
12	64.6	48.6	47.2	46.9	45.0	1.37	1.03	1.00	0.99	0.95
Mean	46.0	29.5	27.8	26.6	24.8	1.85	1.07	1.00	0.95	0.88

change in the ratio. From a practical standpoint there is considerable advantage in blending for not more than 30 sec. and no particular disadvantage in blending this long. Thus in this work the time of blending was standardized at 30 sec. with a stopwatch.

Preparation of Photometer Calibration Chart

During the summer and early fall of 1947, the 24-hour composite samples of 28 raw sewage, 16 primary effluents, and 32 final effluents at Wards Island, after routine testing for Gooch suspended solids and B.O.D., were processed in the blendor and dilutions subjected to photometer tests. Since 400 to 600 ml. or the remaining contents of the composite bottles were blended, a repeat Gooch determination on the homogenized sample was made and used in the preparation of a photometer calibration chart. Two or more distilled water dilutions of a single sample were tested in the photometer so that a minimum of 80 photometer tests on each of three types of sewage was available for calibration purposes. The data were marshalled into groups of a similar transmission, averaged, and plotted on semilogarithmic paper, assuming the application of Beer's Law.

The "best fit" straight line curves were then drawn, one applicable to raw sewage and primary effluents, and another applicable to aeration tank liquors and final effluents. These curves are presented in Figure 2. It will be noted that the curves have their origin (0 p.p.m. suspended solids) at 96 per cent transmission on the logarithmic scale, and the percentage transmission for 100 p.p.m. suspended solids is 19.2 for raw sewage and primary effluent and 31.7 for final effluents and aeration tank liquors.

Results

Using the calibration chart for estimating the suspended solids, a comparison was made of the homogenized and unhomogenized Gooch tests and of

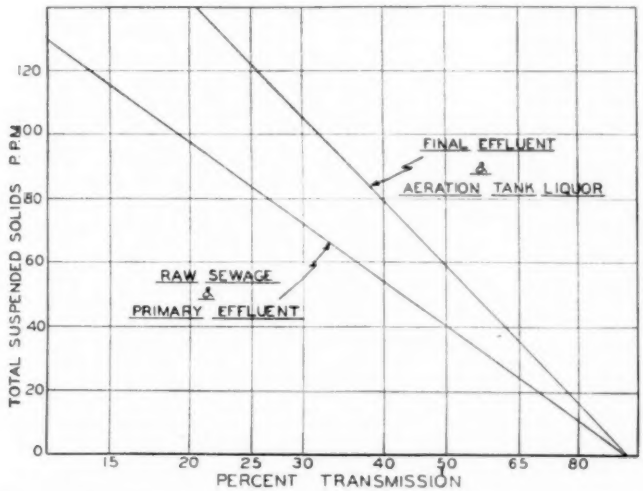

FIGURE 2.—Photoelectric calibration chart. For converting percentage transmission of light to parts per million total suspended solids. A blended sample having a 20-mm. light path is placed 145 to 165 mm. from photo-cell. The sample is blended in a Waring Blendor for 30 sec. before dilution with distilled water if necessary.

the photo-estimate. The results for raw sewage, primary effluent and final effluents are presented in Tables III, IV, and V, respectively, in the order of the magnitude of the homogenized Gooch test.

Raw Sewage

An inspection of Table III will show both good and poor agreement between the three methods of determining total suspended solids of raw sewage. This is not surprising considering the characteristics of raw sewage. The unhomogenized samples contain floating and suspended particles, such as paper, that measure as much as an inch in one dimension. Other particles are small but consolidated and settle extremely rapidly.

TABLE III.—Comparison of the Homogenized and Unhomogenized Gooch Tests and the Photo-estimate of Raw Sewage Suspended Solids

Gooch Tests		Photo-Estim. C (p.p.m.)	B/A	C/A	C/B
Homog. A (p.p.m.)	Unhomog. B (p.p.m.)				
95	109	104	1.148	1.094	0.954
100	127	104	1.270	1.040	0.818
104	115	110	1.104	1.058	0.956
104	112	102	1.077	0.981	0.910
104	148	130	1.420	1.250	0.880
105	133	111	1.265	1.056	0.834
106	129	142	1.218	1.340	1.100
110	123	114	1.118	1.035	0.927
116	167	120	1.438	1.032	0.875
119	116	114	0.974	0.957	0.982
120	127	117	1.059	0.975	0.922
124	140	120	1.130	0.968	0.857
124	117	126	0.942	1.014	1.077
126	151	124	1.199	0.984	0.821
129	122	120	0.946	0.930	0.983
130	144	114	1.107	0.877	0.792
130	127	120	0.976	0.923	0.944
134	184	130	1.372	0.970	0.706
135	147	130	1.089	0.962	0.884
135	149	127	1.102	0.941	0.852
136	134	126	0.984	0.926	0.940
137	177	132	1.290	0.962	0.746
143	138	164	0.965	1.147	1.188
143	151	137	1.056	0.958	0.906
147	164	132	1.116	0.898	0.804
155	186	141	1.199	0.908	0.758
158	238	162	1.504	1.023	0.681
168	184	168	1.094	1.000	0.913
Mean			1.149	1.007	0.870
Standard Deviation of Mean			0.173	0.100	0.125

The arbitrary selection of 100 ml. or less for test purposes is hardly representative even when using extreme care. On the other hand, the homogenization of a large sample such as 400 to 600 ml. permits the selection of a representative 100-ml. subsample for the Gooch test and a smaller amount for the photo-estimate.

The mean suspended solids values of the 28 tests reported in Table III, 126.3, 145, and 126.5 p.p.m., for homogenized Gooch, standard Gooch, and the photo-estimate, respectively. The poor agreement shown by the gravimetric and the photo-estimate of homogenized samples as against the standard Gooch test is evidence of the lack of representative sample in the latter test rather than the loss of filterable solids by the blending treatment.

In the ratio of the photo-estimate to the homogenized Gooch test in column 5, there are only five tests where these two methods deviated from each other by more than plus or minus 10 per cent, while in 13, or 46.4 per cent of the cases, the ratio of unhomogenized Gooch to homogenized Gooch tests deviated from the mean ratio by more than plus or minus 10 per cent. Until there is substantial improvement in the standard Gooch technique of testing raw sewage, the photo-estimate of homogenized samples appears reliable.

Primary Effluent

An inspection of Table IV will show a much better correlation of unhomogenized Gooch, homogenized Gooch, and photo-estimated suspended solids. Unquestionably this is due to the lesser amount of coarse settleable solids in the primary effluents and the relative

TABLE IV.—Comparison of the Homogenized and Unhomogenized Gooch Tests and the Photo-Estimate of Suspended Solids in Primary Effluents

Gooch Tests		Photo-Estim. C (p.p.m.)	B/A	C/A	C/B
Homog. A (p.p.m.)	Unhomog. B (p.p.m.)				
112	135	112	1.204	1.000	0.829
112	106	112	0.946	1.000	1.056
115	128	118	1.112	1.026	1.026
115	120	107	1.043	0.930	0.930
117	121	123	1.033	1.050	1.017
118	122	119	1.032	1.008	0.976
119	111	122	0.933	1.024	1.100
124	130	118	1.048	0.952	0.907
124	117	119	0.943	0.959	1.018
128	121	110	0.945	0.859	0.908
132	127	124	0.963	0.938	0.976
137	131	110	0.955	0.802	0.839
143	150	146	1.049	1.021	0.973
147	148	138	1.005	0.938	0.932
165	160	150	0.968	0.908	0.937
182	206	166	1.131	0.912	0.806
Mean			1.019	0.958	0.952
Standard Deviation of Mean			0.078	0.065	0.080

ease of obtaining a representative 100-ml. sample.

At least half of the effluents tested contained a variable fraction of waste activated sludge. Since homogenized activated sludge solids have a substantially lower light transmission per unit of suspended solids than does raw sewage, the correlation of the photo-estimate with either of the Gooch methods is surprisingly good. With more experience in testing with the photometer a correction to account for waste activated sludge or other returned liquors could be applied to improve the photo-estimate.

Excluding the last two tests, which contained a high amount of waste activated sludge, the mean suspended solids of 14 tests are 124.5, 126, and 120 p.p.m. for the homogenized Gooch, the standard Gooch, and the photo-estimate, respectively.

Final Effluents

An inspection of the 32 final effluent determinations in Table V will show great discrepancies between methods. An explanation for this variation may be in the inability to obtain representative 200-ml. sub-

TABLE V.—Comparison of the Homogenized and Unhomogenized Gooch Tests and the Photo-Estimate of Suspended Solids in Final Effluents

Gooch Tests		Photo-Estim. C (p.p.m.)	B/A	C/A	C/B
Homog. A (p.p.m.)	Unhomog. B (p.p.m.)				
2	8	10	4.00[1]	5.00[1]	1.25
9	5	10	0.55	1.11	2.00
9	14	14	1.55	1.55	1.00
9	16	17	1.78	1.89	1.06
12	8	10	0.67	0.83	1.25
13	12	13	0.92	1.00	1.08
13	12	15	0.92	1.15	1.25
16	11	8	0.69	0.50	0.73
16	16	17	1.00	1.06	1.06
16	27	18	1.69	1.12	0.67
17	26	23	1.53	1.35	0.88
18	10	15	0.61	0.83	1.50
18	12	10	0.67	0.56	0.83
19	11	14	0.58	0.74	1.27
19	17	17	0.89	0.89	1.00
20	20	17	1.00	0.85	0.85
21	22	20	1.05	0.95	0.91
22	8	15	0.36	0.68	1.88
24	9	12	0.37	0.50	1.34
24	18	21	0.74	0.87	1.17
25	10	11	0.40	0.44	1.10
25	35	25	1.40	1.00	0.71
25	21	21	0.84	0.84	1.00
25	23	24	0.92	0.96	1.04
26	15	20	0.58	0.77	1.33
27	9	10	0.33	0.37	1.11
27	14	19	0.52	0.70	1.36
27	19	22	0.70	0.81	1.16
29	36	25	1.24	0.86	0.69
32	41	38	1.28	1.19	0.93
33	38	34	1.15	1.03	0.90
34	22	25	0.65	0.74	1.14
Mean 20.4	17.4	17.8	0.99	1.03	1.00[2]
Standard Deviation of Mean Ratio			0.41	0.34	0.32

[1] Omitted in standard deviation.
[2] Assumed central tendency.

samples for the standard Gooch test when the effluent contains large activated sludge floc or, not infrequently, several consolidated particles (grease balls).

In the low suspended solids range the routine Gooch weighing errors account for significant discrepancies. The photo-estimate, too, is subject to increased errors which could be largely overcome by the selection of a cuvette having a longer light path. Thus the 20-mm. cuvette used in these studies would be satisfactory for effluents of 20 p.p.m. suspended solids or greater, and if it was desirable to estimate effluents in 10 p.p.m. range, a 50-mm. light path cuvette would be needed.

Considering only the 12 tests having a photo-estimate of 20 p.p.m. or more, the average by the homogenized Gooch, the standard Gooch, and the photo-estimate was 26.5, 26.3, and 25 p.p.m., respectively. An inspection of the ratios in columns 4, 5 and 6 indicates that the unhomogenized and homogenized Gooch tests deviated from each other to a greater degree than the ratio of photo-estimate to either test.

Routine Tests

All routine weekday samples of raw sewage, primary effluent and final effluents from the activated sludge plant at Ward's Island were homogenized and the suspended solids photo-estimated according to Figure 2, after abstraction of samples for routine (unhomogenized) suspended solids and B.O.D.

Of a total of 42 sewages the mean ratio of photo-estimate to unhomogenized Gooch test was 0.980 and the median was 1.007. In no case did the deviation of an individual test exceed plus or minus 25 per cent. In 3 cases (7 per cent) the deviation exceeded plus or minus 20 per cent; in 10 cases (24 per cent) the deviation exceeded plus or minus 15 per cent; in 17 cases (40 per cent) the deviation exceeded plus or minus 10 per cent.

Of a total of 42 primary effluents, the mean ratio of photo-estimate to unhomogenized Gooch test was 1.001 and the median was 1.024. In 2 cases (5 per cent) the deviation exceeded plus or minus 20 per cent; in 8 cases (20 per cent) the deviation exceeded plus or minus 15 per cent; in 12 cases, (30 per cent) the deviation exceeded plus or minus 10 per cent.

Of a total of 80 activated sludge effluents, the mean ratio of photo-estimate to unhomogenized Gooch test was 1.027 and the median was 1.014, or an average of 1.02. In 8 cases, or 10 per cent of the time, the deviation exceeded plus or minus 25 per cent; in 14 cases, or 18 per cent of the time, the deviation exceeded plus or minus 20 per cent; in 21 cases, or 26 per cent of the time, the deviation exceeded plus or minus 15 per cent; in 39 cases, or 49 per cent of the time, the deviation exceeded plus or minus 10 per cent.

Accuracy of Gooch Tests

As a guide in evaluating the merits of homogenizing sewage in order to obtain representative subsamples for Gooch analysis, a single 4-gal. sample of raw sewage was intimately mixed while dispensing the sewage into ten small and one large bottle. The contents of the large bottle were then homogenized for 30 sec. in the Waring Blendor and, after thorough and continuous mixing, dispensed into ten small bottles. Preservative was added and a set of two bottles was sent to each of five laboratories on each of two days to be included in the daily routine of suspended solids tests. Duplicate tests on each of the homogenized and unhomogenized samples were performed at some laboratories, so a total of fifteen check results by each of two methods were available for study.

The results are presented in Table VI showing the total and volatile suspended solids in parts per million (and the percentage volatile suspended) by the Gooch test. The mean total sus-

TABLE VI.—Check Results on the Gooch Suspended Solids of a Single Sample Unhomogenized and Homogenized

Laboratory	Size of Sample (ml.)	Total Suspended Solids		Vol. Suspended Solids		Percentage Volatile		Ratio Total Susp. Sol. Unhom. to Homog.
		Homog. (p.p.m.)	Unhomog. (p.p.m.)	Homog. (p.p.m.)	Unhomog. (p.p.m.)	Homog. (%)	Unhomog. (%)	
A	25	161	152	140	110	87.0	72.4	0.94
	50	156	150	136	130	87.2	86.6	0.96
	100	180	145	154	122	86.0	84.1	0.76
B	50	150	140	126	120	84.0	86.0	0.93
	50	146	132	117	113	80.0	86.0	0.89
	50	190	170	156	143	82.0	85.0	0.88
	50	170	180	146	158	86.0	88.0	1.06
C	50	180	162	152	136	84.5	84.0	0.89
	50	176	184	150	152	85.3	82.6	1.04
	50	172	182	142	138	82.6	75.8	1.06
	50	172	178	140	136	81.5	76.3	1.04
D	100	148	138	124	115	83.8	83.1	0.93
	100	140	151	117	125	83.5	82.8	1.07
E	100	148	157	123	127	83.2	81.2	1.06
	100	150	143	135	127	90.0	88.8	0.95
Mean	—	163	157.5	137	137	84.1	86.9	0.96

pended solids was 163 and 157.5 p.p.m. on the homogenized and unhomogenized sample, respectively. The mean volatile suspended solids was 137 p.p.m. by each method. Of greater significance, however, is the rather wide variation of individual tests more or less irrespective of the laboratory, each of which use the same uniform technique.

The average deviation from the mean homogenized tests was minus 11.5 p.p.m. to plus 14.2 p.p.m., or a maximum deviation of plus 27 p.p.m. The standard deviation was found to be 14.9 p.p.m. (plus or minus 9.15 per cent).

The average deviation from the mean unhomogenized total suspended solids was minus 12.2 and plus 18.5 p.p.m., or a maximum of 26.5 p.p.m. The standard deviation was found to be 16.8 p.p.m. or 10.7 per cent.

Considering the standard deviations of total suspended solids, it may be stated that the homogenized Gooch tests are 100 (16.8–14.9)/14.9 or 12.7 per cent more representative than the unhomogenized total suspended solids. Since this particular sample of raw sewage was much more uniform in appearance than usual, it is quite probable that 10 to 15 per cent represents the lower limit of improved accuracy by homogenization.

Considering the volatile suspended solids, the standard deviation was 12.8 p.p.m., or 9.34 per cent, for homogenized samples, and 14.6 p.p.m., or 10.65 per cent, for unhomogenized samples. Thus the homogenized tests were 14 per cent more representative.

Summary

Many recent articles have attested to the value and limitations of photometric determinations. In this study a satisfactory estimate of the total suspended solids in sewage was made by means of a Waring Blendor for uniform particle distribution and a

photometer for recording the transmission of light.

The test is rapid in that ten samples may be tested in 30 min. or less. Thus it is a particularly promising sewage treatment control index, and has been used to determine the diurnal fluctuation of sewages at frequent intervals.

Samples of raw sewage, settled sewage, mixed activated sludge liquor, and activated sludge effluents were processed for 30 sec. with a Waring Blendor. The homogenized samples were then diluted with distilled water, if necessary, to within the working range of the photometer.

A Photo Volt Model 420E Lumetron with a 402M light filter, and a 15-ml. cuvette having a 20-mm. light path, was used. With the rectangular cuvette placed 145 to 165 mm. from the photo-cell to obtain maximum scattering of light, the accurate working range is from 20 to 120 p.p.m. suspended solids, and corresponds to transmission readings of 15 to 80 scale readings, depending on the type of sample.

The calibration curve for raw and settled sewage is a straight line when the parts per million of suspended solids is plotted linearly against the logarithm of the percentage transmission of light. Zero and 120 p.p.m. total suspended solids corresponds to 96 and 14 per cent transmission, respectively, for Ward's Island sewage.

The calibration chart for final effluents and mixed liquor from the activated sludge plant is a straight line on semilogarithmic paper. Zero and 120 p.p.m. total suspended solids corresponds to 96 and 25.5 per cent transmission, respectively.

Since a large sample of 400 to 800 ml. is homogenized in the Waring Blendor, the subsample used for testing purposes is often more representative than the 50 to 100 ml. normally used for the Gooch test.

Conclusions

Photelometers operating on compensating or constant current and sample compartments which permit maximum scattering of light are readily adaptable to a satisfactory estimate of the total suspended solids of sewage. Samples subjected to the photelometer tests should first be processed by some type of homogenization which will assure reasonably uniform particle distribution and range of size. Moderate homogenization of sewage containing coarse particles or activated floc is a desirable adjunct in obtaining representative samples for the Gooch test.

Studies are suggested on the development of continuously recording photelometer readings on homogenized samples for the control of sewage plant operations.

APPLICATION OF A NEW RESIDUAL CHLORINE METHOD TO EFFLUENT CHLORINATION *

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The bactericidal action of chlorinated sewage and sewage effluents that fail to show a chlorine residual by the ortho-tolidine (OT) or starch-iodide methods has been previously studied (6, 7, 8, 10). These studies have shown that the bacterial reduction is not due entirely to the immediate action of the chlorine on the bacteria before it reacts with the sewage, but to a bactericidal substance that persists in solution. Although the observed bactericidal activity has been attributed to the formation of chloramines (7), this could not be definitely established because no method was available for the accurate titration of such chloramines in sewage or sewage effluents.

Recently a method of titrating chlorine residuals of sewage and sewage effluents, chlorinated to less than an OT residual, has been reported by Marks, Joiner and Strandskov (4), and it was found that these residuals correlated well with bactericidal action. In this method an excess of the standard reagent, phenylarseneoxide, is added to the sample to be titrated. Potassium iodide is then added and, as the iodine is liberated, it immediately reacts with the reagent. The pH of the sample is then reduced to 2.5 or less with hydrochloric acid and the unreacted phenylarseneoxide is titrated with a standard iodine solution. At the low pH, iodine is sufficiently stable in the presence of sewage to permit an accurate measure of the unreacted phenylarseneoxide. The end-point is determined amperometrically using the Wallace & Tiernan titrater described by Marks and Glass (2). The development of a color with starch can also be used as the end-point but it is not as accurate as the amperometric method.

The purpose of the work reported here was to compare this method, under actual operating conditions, with the OT method for the determination of bactericidal chlorine residuals in sewage effluents.

Two trickling filter plants were selected for this study. Plant No. 1 had a secondary settling tank between the trickling filters and the final holding tank, while in Plant No. 2 the effluent flowed directly from the trickling filters into the final holding tank. In both cases the effluent was chlorinated just before it entered the final holding tank.

Experimental Procedure

A 500-ml. sample was collected for each bacteriological and chlorine residual determination. For each series one sample was collected just prior to chlorination.

The time required for the effluent to flow through the holding tank was calculated from the rate of flow and the size of the tank. After the calculated time period had elapsed a sample was collected from the outlet of the tank. In this way, samples of approximately the same effluent before and after the chlorine contact time were obtained. An aliquot was immediately treated with sodium sulfite to inactivate the chlorine and thereby arrest the bactericidal action.

* Presented at 21st Annual Meeting, Central States Sewage Works Assn., Milwaukee, Wis., June 18–19, 1948.

Chlorine residuals of the unreduced effluent were determined by the OT method and by titration as rapidly as possible. Appropriate dilutions of the sodium sulfite treated aliquots were made and plated in nutrient agar and incubated at room temperature for 48 hours to obtain total bacterial counts. Presumptive most probable numbers of coliform organisms were determined by standard methods (9). Once each day samples of chlorinated and unchlorinated effluent were collected for the determination of reduction in 5-day B.O.D. obtained by the chlorination process.

Results

The experiments were conducted over a period of about 2 months at each plant. An average of four samples were collected and analyzed each day. The chlorine residuals obtained by the OT and titration method at Plant No. 1 are compared in Table I. The titration values represent an average of several samples, all of which showed the corresponding OT values indicated in the first column.

At the higher chlorine residual levels, the OT values are approximately 10 per cent of the values obtained by titration, but this drops to

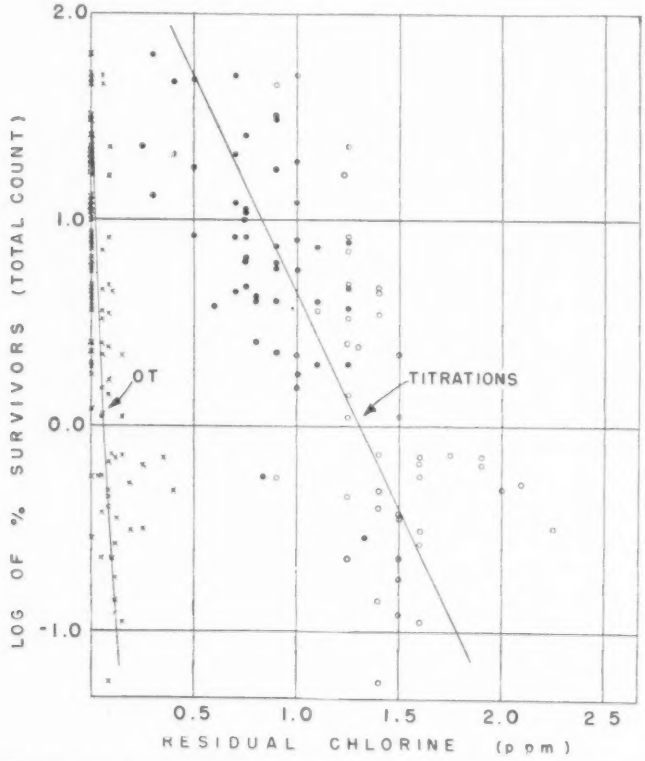

FIGURE 1.—Reduction of total bacteria count as a function of chlorine residuals at Plant No. 1. Contact time 60 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

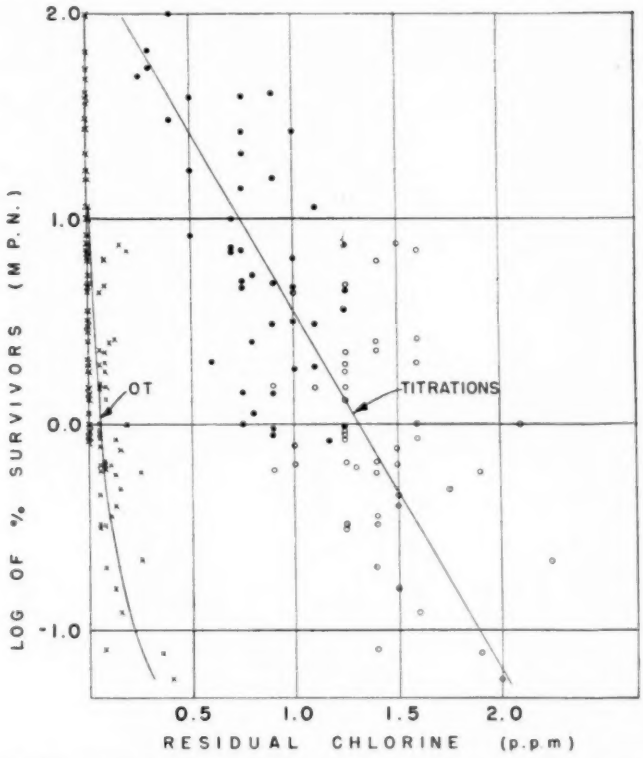

FIGURE 2.—Reduction of MPN of coliform organisms as a function of chlorine residual at Plant No. 1. Contact time 60 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

approximately 4 per cent at the lowest concentration. In addition to these results, a large number of the samples analyzed gave zero OT readings, but showed a positive titration value as high as 1 p.p.m. chlorine.

TABLE I.—A Comparison of Chlorine Residuals in Effluent as Determined by OT and Titration at Plant No. 1

Chlorine Residual (p.p.m.)		
OT	Titration	Difference
0.25	2.1	1.85
0.18	1.9	1.72
0.15	1.6	1.45
0.12	1.5	1.38
0.10	1.4	1.30
0.08	1.4	1.32
0.05	1.2	1.15

Similar results were obtained at Plant No. 2, and are recorded in Table II. They differ, however, in that the OT readings are a much higher percentage of the titration values than those obtained at Plant No. 1. Again a large number of samples gave a zero reading by the OT method, but a positive titration value.

In Figures 1 through 6 are plotted the chlorine residuals, as determined by the two methods, against the log of the per cent of organisms that survived the treatment. The data in Figures 1 and 2 represent the results obtained at Plant No. 1.

TABLE II.—A Comparison of Chlorine Residuals in Effluent as Determined by OT and Titration at Plant No. 2

Chlorine Residual (p.p.m.)		
OT	Titration	Difference
2.0	3.5	1.5
1.5	2.9	1.4
1.0	2.6	1.6
0.9	2.2	1.3
0.7	1.9	1.2
0.6	1.3	0.7
0.4	1.4	1.0
0.3	1.4	1.1
0.2	1.2	1.0
0.15	0.95	0.8
0.10	1.0	0.9
0.08	0.53	0.45

Although the points in Figure 1 that represent the titration residuals are widely scattered, they do show that the percentage reduction in the total bacterial count is related to the chlorine residual obtained in this manner. There is also a relationship of OT residual to bacterial reduction, but this is not consistent because a reduction anywhere from zero to more than 99 per cent in bacterial count can be obtained when no chlorine residual can be shown by the OT method.

The data in Figure 2 represent the reduction in presumptive most probable numbers of coliform organisms

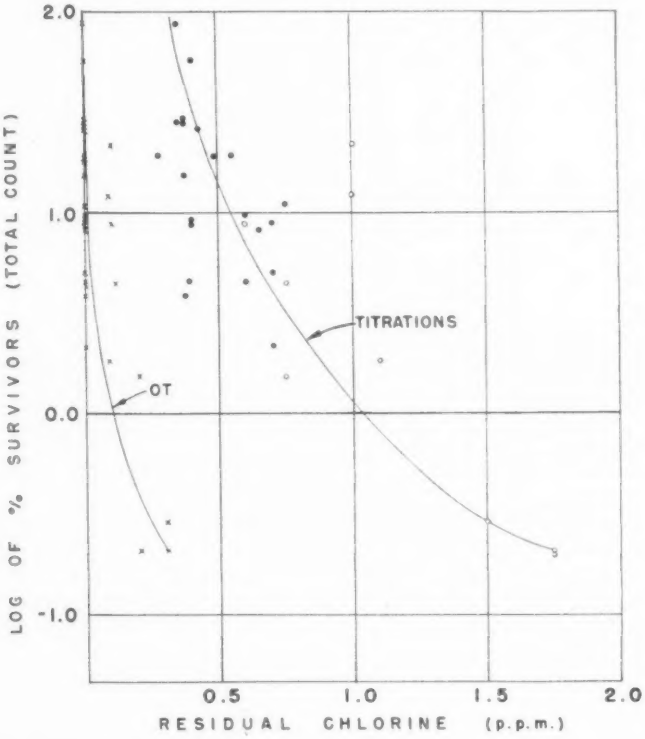

FIGURE 3.—Reduction of total bacteria count as a function of chlorine residuals at Plant No. 2. Contact time 20 to 30 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

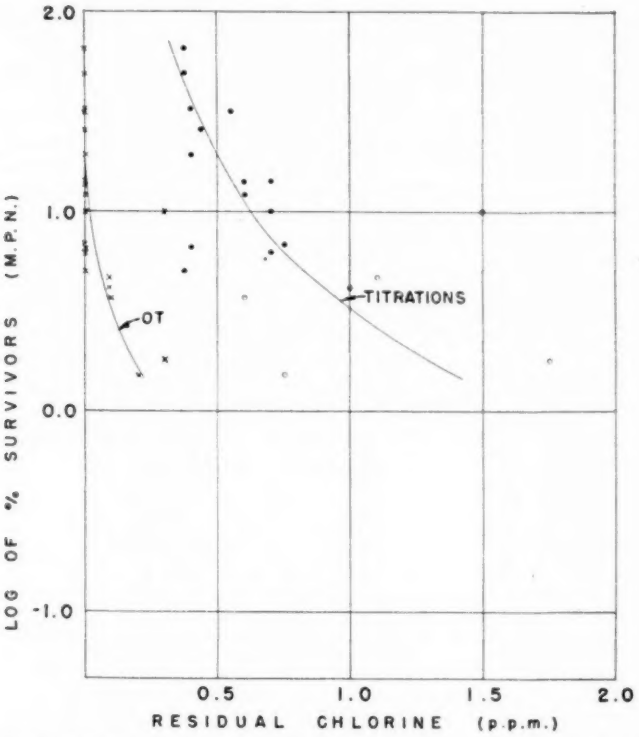

FIGURE 4.—Reduction of the MPN of coliform organisms as a function of the chlorine residual at Plant No. 2. Contact time 20 to 30 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

plotted against the two types of residuals. The same relationship exists as was observed for the total count in Figure 1.

The data gathered at Plant No. 2 are presented in Figures 3, 4, 5 and 6. The holding times varied over a wide range at this plant because of the wide variety of flow rates obtained on various days and at various times during the day. Because the holding time affects the degree of killing by any given concentration of disinfectant, two ranges of holding times were used in preparing the graphs. Although the results obtained at this plant, for the holding times selected, are not as numerous as those obtained at Plant No. 1, nor do they cover as wide a range of titration residuals, they do present a similar picture.

A wide variation in degree of bacterial reduction is again obtained with zero OT readings, but the degree of reduction is a function of the titration residuals. In contrast to Figures 1 and 2, curves have been drawn to fit the data in Figures 3, 4, 5, and 6 rather than straight lines. This appeared to be the type of line that best fit the data. Because the points are so widely scattered, it is also possible

that the best line for the data in Figures 1 and 2 is not a straight line, but should also be slightly curved.

It is reasonable, as pointed out by Rahn (5), that a mixture of bacteria such as is found in sewage effluents will give a different killing pattern from that obtained with a pure culture. In this case, as the concentration is increased, a point could be reached at which the more resistant organisms become a sufficiently high percentage of the total survivors to influence the results and gradually decrease the slope of the killing curve. It is also possible that the bacteria that survive treatment with the lower concentration are more resistant because they are protected by suspended particles. This would tend further to reduce the slope of the line.

The experiments reported here are further complicated by the possibility that chloramines possessing various degrees of bactericidal activity are formed. This could explain the upper part of the curves, where the percentage of reduction in bacterial count is less than would be expected from the residuals obtained by titration.

An attempt was also made to study the effect of these chlorine residuals on the biochemical oxygen demand of the effluents. These experiments were not very successful, however, because the demand of the unchlorinated

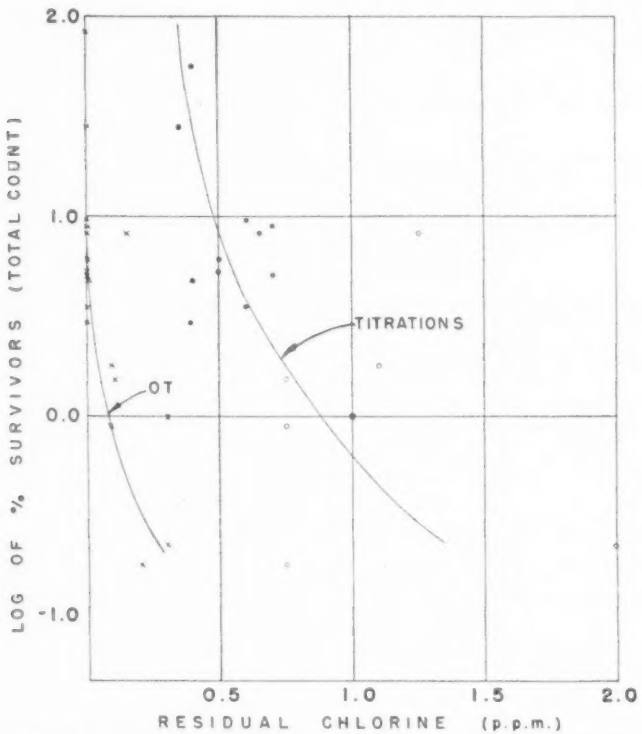

FIGURE 5.—Reduction of total bacterial count as a function of chlorine residuals at Plant No. 2. Contact time 30 to 40 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

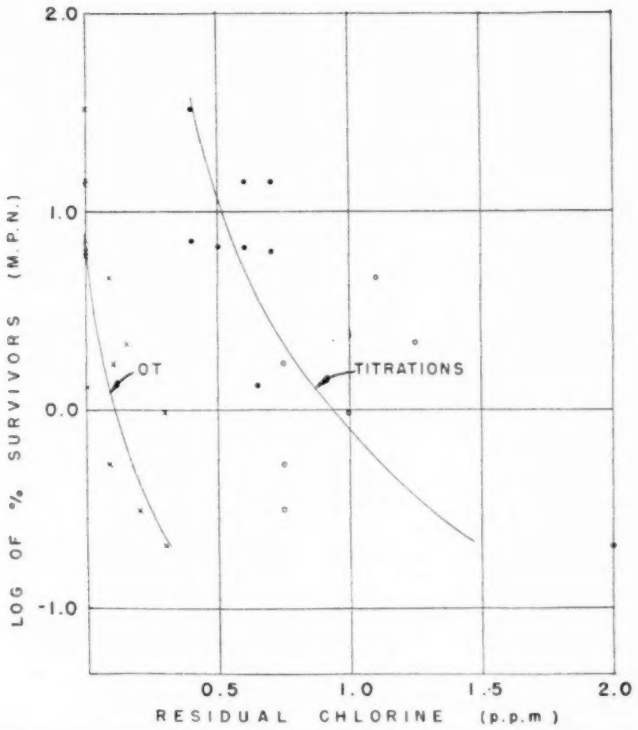

FIGURE 6.—Reduction of the MPN of coliform organisms as a function of chlorine residual at Plant No. 2. Contact time 30 to 40 min.; solid points represent titrated residuals of samples which gave zero OT readings, open points denote titrated residuals of samples which gave OT readings.

effluent was on the average only about 20 p.p.m. At this low original oxygen demand the reductions obtained even with high OT residuals were not consistant.

Discussion and Conclusions

The residuals obtained on chlorinated sewage effluents by the OT method are only a fraction of those obtained by the titration method developed by Marks and co-workers (4). Indeed, a zero reading with OT is obtained on a large number of samples which give titration residuals as high as 1 p.p.m. chlorine. The bactericidal action of the chlorinated effluent correlates well with the titration residuals, but does not correlate with the OT residuals because of the large variation in killing obtained with zero OT readings. Such bactericidal action in sewage effluents, chlorinated to less than their demand, has been previously attributed to the formation of chloramines, but this could not be demonstrated because no method was available by which they could be measured. Using the new titration method, Marks and Joiner (3) have recently shown by chlorinating solutions of pure amino acids and bases, that chloramines of this type do give this discrepancy between residuals obtained by the OT method and the titration method. Furthermore, they

have demonstrated that the amount of the discrepancy, in the two types of residuals, is very different for the different types of chloramines. The difference in the discrepancy between the two methods, observed at the two sewage plants reported here, could be caused by a difference in the predominating types of amines available for chlorination.

Although, as has been stressed by Mallman and Shephard (1), the per cent reduction in bacterial counts of sewage effluents is not always a good measure of the practical effectiveness of the process used for sterilization, it is necessary to use such a measure for the purpose of comparison when the original counts vary as they do in this type of experiment. A 99 per cent reduction in total count in these experiments usually resulted in a count somewhere between 100 and 1,000 organisms, while the presumptive most probable number of coliform organisms ranged from 10 to 500 per ml. at 99 per cent reduction.

The titration method gives a much more reliable measure of chlorine residuals that give bacterial reductions of this order than does the OT method. Reductions of this order are satisfactory in most cases, as the bacterial counts of the streams into which the effluents flow are usually higher. It is also expected that a reduction in B.O.D. would be obtained by these residuals, although this could not be determined in these experiments because of the low B.O.D. of the untreated effluent.

Numerous studies on prechlorination of sewage have shown that chlorination to less than an OT residual is effective in bacterial reduction and in control of hydrogen sulfide production, sewage septicity, and sludge bulking, as well as the control of sewage plant odors in general. It has, however, been difficult to control this type of chlorination because of the lack of chemical control methods. Now that a method is available for the accurate measurement of such residuals, prechlorination can be applied to these problems in a more intelligent and economical manner.

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EFFICIENCY STUDIES OF A SHALLOW RECIRCULATING SEWAGE FILTER

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This station has been interested in studying small sewage treatment plants with the purpose of determining their efficiency and suitability for the treatment of sewage at small towns. Efficiency studies of the newer type high-rate recirculating filters that were developed and constructed in recent years were not possible during the war because of the need for research on war-connected projects. Early in 1946, arrangements were made with the State Board of Health of Kentucky and the city officials for a study of the new recirculating filter that had recently been completed at Elizabethtown, Ky. The trailer laboratory which had previously been used on the Neosho, Mo., sewage filter study (4) was taken to Elizabethtown and the study was continued from April 8 to May 20, 1946.

Plant Description and Engineering Data

The Elizabethtown, Ky., plant is a single-stage biofiltration plant with two shallow trickling filters normally operated in parallel. Effluent from the final clarifier is recirculated to the inlet of the primary clarifier, the amount of recirculation being controlled by a float valve so that a constant volume of flow is maintained.

The plant is located about a mile west of the center of town and the effluent discharges into a small creek. During the time of the survey, there was more than normal flow in the creek due to frequent spring rains. Industrial wastes are contributed from a laundry, a slaughterhouse and a milk plant. The wastes from the first two are sufficient in volume to have a noticeable physical effect on the sewage. It was noted that at times the entire flow was red in color due to the blood from the slaughterhouse, and there was a daily fluctuation in the temperature of the raw sewage from 16° C. to 25° C. which was ascribed to the laundry waste.

The plant consists of a by-pass control manhole, a comminutor with emergency bar screen, a circular primary settling tank equipped with Dorr Sifeed clarifier and automatic skimmer, two 3-ft. depth circular trickling filters with Dorr Type KC, four-arm distributors, and a final settling tank with a Dorr Type A clarifier with central loading well inlet. The effluent launders of the settling tanks are of an unusual type in that there are no overflow weirs; the effluent is removed by a series of 2-in. diameter circular ports at 24-in. spacing through the concrete wall of the launder. A weir at the outlet from the launder maintains the level in the trough high enough to keep these ports submerged.

Normal Operation

The incoming raw sewage enters the plant through the control chamber and, if not in excess of the capacity of one pump, all of it passes through the plant. Flows in excess of the capacity of one pump automatically pass over the by-pass weir to the plant effluent line.

The sewage from the control manhole passes through the comminutor to the pump suction well, and any defi-

ciency from the capacity of the pump is made up by admitting final clarifier effluent ("recirculation flow") through a float-operated valve and over a ¼-in. steel stop plank 1 ft. 10 in. long. The pump delivers the mixture of raw sewage and recirculation flow to the primary settling tank at a constant rate. The effluent from the primary tank passes to a "division box" where it is divided between the two filters as nearly equally as possible.

The filter effluents are combined to form the influent to the final settling tank. The effluent from the final tank, except for the portion used as recirculation flow, passes to the receiving stream.

A plant flow diagram for normal operation is given in Figure 1.

Series Operation

The plant was sufficiently flexible so that the filters could be operated in

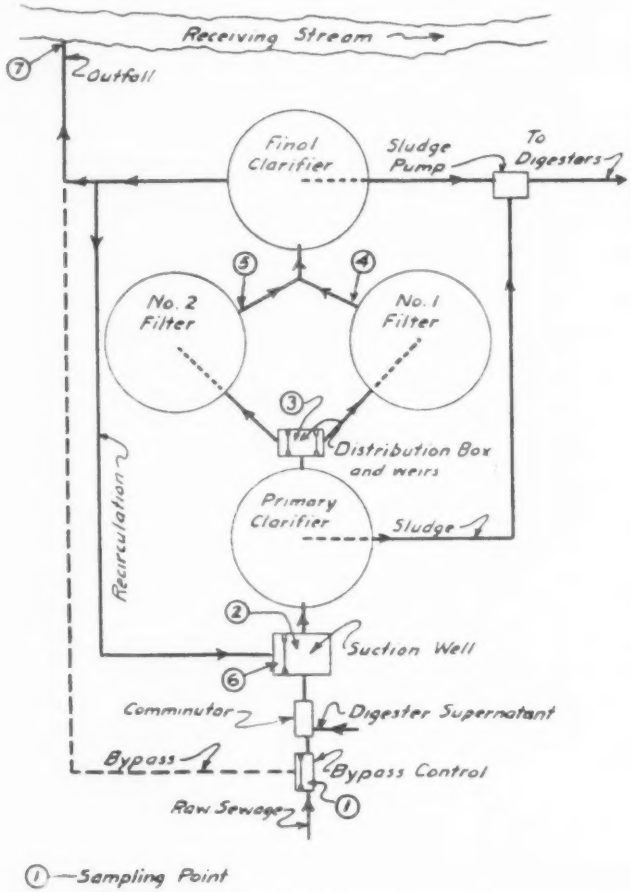

FIGURE 1.—Flow sheet of sewage treatment plant, Elizabethtown, Ky. Parallel filter operation.

TABLE I.—Raw Sewage and Recirculation Flow Rates

	Air Temp. (°C.)	Inf. Temp. (°C.)	Sewage Flow (m.g.d.)[1]			Recirculation Rate (m.g.d.)			R/S[2]
			Max.	Min.	Total Treated (m.g.)	Max.	Min.	Ave.	
First Period—Normal Operation									
Average	—	—	0.809	0.343	0.552	0.590	0.124	0.381	0.69
Maximum	—	—	—	—	0.591	—	—	0.425	—
Minimum	—	—	—	—	0.508	—	—	0.342	—
Second Period—High Recirculation									
Average	—	20	0.573	0.398	0.491	0.535	0.360	0.442	0.90
Maximum	—	20	0.760	0.439	0.538	0.651	0.465	0.487	—
Minimum	—	19	0.468	0.282	0.446	0.494	0.173	0.395	—
Third Period—Filters in Series									
Average	18	19	0.794	0.466	0.626	0.467	0.139	0.294	0.63
Maximum	21	21	—	—	0.777	—	—	0.407	—
Minimum	12	17	—	—	0.526	—	—	0.070	—

[1] Includes digester supernatant returned.
[2] R/S = Recirculation Ratio.

series. During series operation the distribution box discharge to Filter No. 2 was closed, and all settled sewage passed through Filter No. 1 and into Filter No. 2 without intermediate settling.

Flow Measurements

In order to obtain necessary flow measurements, the metal stop plank over which the recirculation flow entered the pump suction well was used as a weir. A float with a rod and pointer and a staff gauge was installed on the up-stream side of the weir, and the gauge was read every half hour over the 24-hour sampling periods.

Two end-contracted weirs were installed in the division box at the outlet of the primary tank, in place of the proportioning stop planks. Readings were taken of the weir head at this point approximately every 45 min. from 9 A.M. to 5 P.M. on one day. The flow was calculated for each of the 13 readings and averaged, and this was taken as the average pump delivery for all computations of flow through the various plant units. Inasmuch as all except one of the readings were from 8¾ in. to 9 in., it is felt safe to assume that the pump consistently maintained the computed delivery of 650 g.p.m. or 0.933 m.g.d. The difference between the pump delivery and the recirculation flow, measured as above, was taken as the raw sewage flow through the plant. The "raw sewage flow" as thus calculated includes the digester supernatant returned.

Table I is a summarization of the flows for the three periods of the test.

The quantity of digester supernatant returned to the raw sewage was considered equal to the volume of sludge and skimmings pumped to the primary digester, as computed from pump delivery and pumping time daily.

Detention periods and vertical flow rates (gal. per sq. ft. surface area per

24 hours) were computed for the two settling tanks. Salt concentration detention tests were made on the settling tanks to estimate the effective detention period.

Distribution tests by means of pans placed along a radius of the filters were made to determine the efficiency of distribution of the sewage. Salt concentration tests were made on the filters when they were operating in series to determine the flow-through time.

Settling Tank Detention Period Tests

The detention period of the settling tanks was determined by dumping about 30 lb. of salt dissolved in approximately 25 gal. of effluent into the tank influent. As soon as the salt had been added, samples of the effluent were taken every 5 min. and titrated to determine the chloride concentration, until the chloride concentration returned to the normal determined just before the test was started. In the case of the primary tank, the chloride concentration had nearly returned to normal after 210 min., and then again started to increase due to recirculation from the final tank.

It is recognized that the chloride ion concentration method of measuring detention time periods in tanks is not ideal. As pointed out by Camp (1), short-circuiting occurred when he attempted to use this method. It should be remembered, however, that he was working with small rectangular tanks and clear waters which involved greater differences in specific gravity than were involved here between very dilute salt solutions and sewage.

The results of these determinations were plotted on rectangular coordinate paper and Hazen's probability paper, and analyzed in accordance with Morrill's method (2). These curves are shown in Figures 2 and 3 for the primary tank. The justification for in-

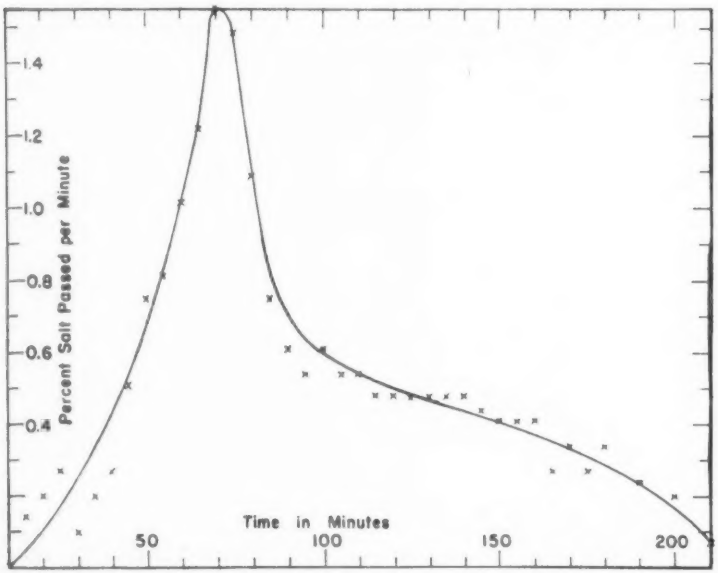

FIGURE 2.—Salt dispersion test curve for primary clarifier; flow 650 g.p.m., mean time of flow 83 minutes.

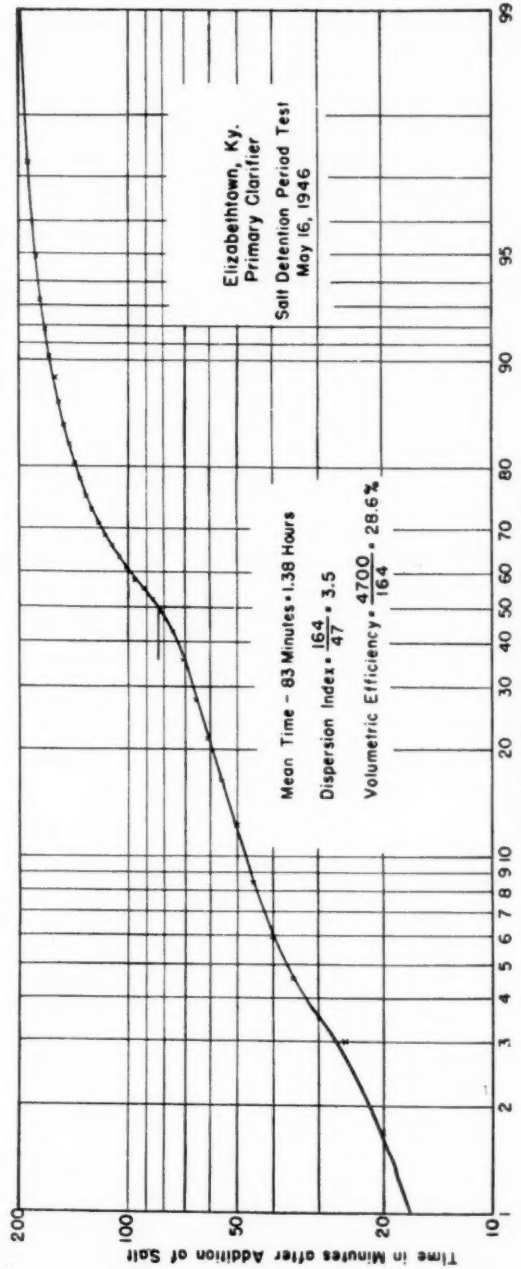

FIGURE 3.—Primary tank salt detention period test, May 16, 1946.

terpreting the time required to discharge 50 per cent of the salt into the effluent as the actual mean detention time is open to question. However, in spite of possible disturbances due to density differences, it is believed that these salt detention measurements have some merit and, in the case of the secondary tank at least, give another criterion indicating poor performance. Consequently the times required for the removal of 50 per cent of the salt have been calculated and are referred to in this paper as the estimated mean detention periods by the salt test.

The primary tank had a theoretical detention period of 135 min., or 2.25 hours, but Figure 3 shows that the estimated mean detention period by the salt test was 83 min., or 1.38 hours —only 61.4 per cent of the theoretical period. The peak of salt discharge, or "mode," was reached in 70 min., or 84 per cent of the estimated mean detention period. The "volumetric efficiency" (Morrill) of this tank,

$$\frac{\text{Min. to pass 10\% of salt}}{\text{Min. to pass 90\% of salt}} \times 100,$$

was 28.6 per cent. The overflow or vertical flow rate for this tank was computed to be 820 gal. per sq. ft. per 24 hr., a very conservative figure for a primary clarifier.

TABLE II.—Clarifier Data

	Primary Clarifier	Final Clarifier
Overflow Rate (gal. sq. ft. 24 hr.)	820	820
Theoretical Detention (hr.)	2.25	1.78
Estimated Mean Detention (hr.)	1.38	1.22
Mean/Theoretical	0.614	0.685
Peak Salt Discharge (mode) (hr.)	1.17	0.58
Mode/Mean	0.845	0.475
Volumetric Efficiency (%)	28.6	19.5

The same procedure for the salt test was used at the final settling tank. The data for both primary and final settling units are summarized in Table II.

Filter Distribution Tests

Pan tests for sewage distribution on the two filters were made on two different occasions: first, during parallel operation of the filters and later while the filters were operating in series.

Metal trays 10-in. wide by 24-in. long by 4-in deep, each containing four 6-in. wide sections, were placed end to end in a trench excavated in the filter stone along a radius of the filter. The filter distributor was allowed to make a predetermined number of revolutions, and the trays were then removed and the average depth of water in each section was measured to the nearest $\frac{1}{16}$ inch. This depth in each section thus represented the depth applied to the corresponding 6-in. concentric ring of filter surface in a given time. Duplicate runs were made on each filter and averaged. From these results, distribution data, as suggested by Walton (3), as well as the standard deviation and coefficient of variation according to standard statistical procedure, were computed and are tabulated in Table III. The terms used in this table may be defined briefly as follows:

TABLE III.—Filter Distribution Data[1]

	No. 1 (West) Filter	No. 2 (East) Filter
Parallel Operation		
Dosing Rate (g.p.m.)	325	325
Coefficient of Area	0.997	0.997
Coefficient of Distribution	1.56	1.60
Dosing Ratio	1.77	1.84
Mean Depth (1/16 in.)—M	16.1	14.7
Standard Dev. (1/16 in.)—SD	4.83	4.90
Coefficient of Variation $\left(\frac{SD}{M} \times 100\right)$	30.0	33.3
Series Operation		
Dosing Rate (g.p.m.)	650	650
Coefficient of Area	0.997	0.997
Coefficient of Distribution	1.54	1.56
Dosing Ratio	1.88	1.62
Mean Depth (1/16 in.)—M	16.2	19.4
Standard Deviation (1/16 in.)—SD	4.84	6.44
Coefficient of Variation $\left(\frac{SD}{M} \times 100\right)$	29.9	33.2

[1] Filter No. 2 in series operation was rated on five revolutions of distributor. All other tests made on four revolutions.

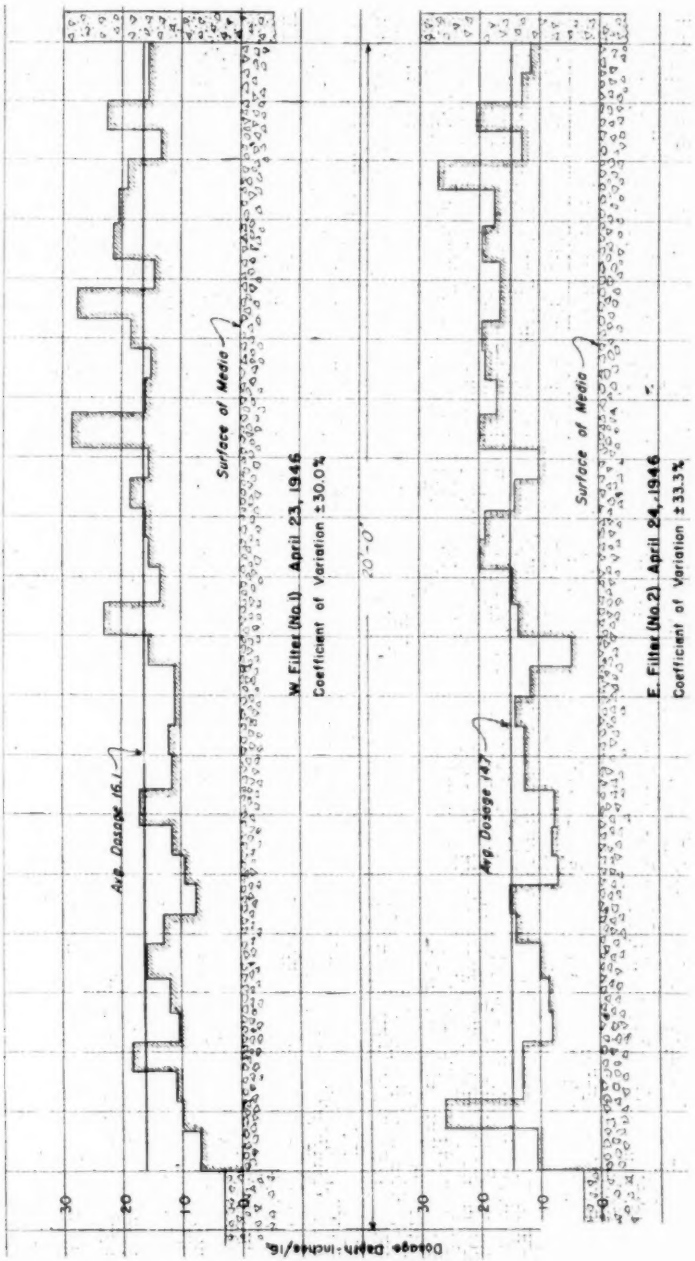

FIGURE 4.—Filter dosage distribution in parallel operation.

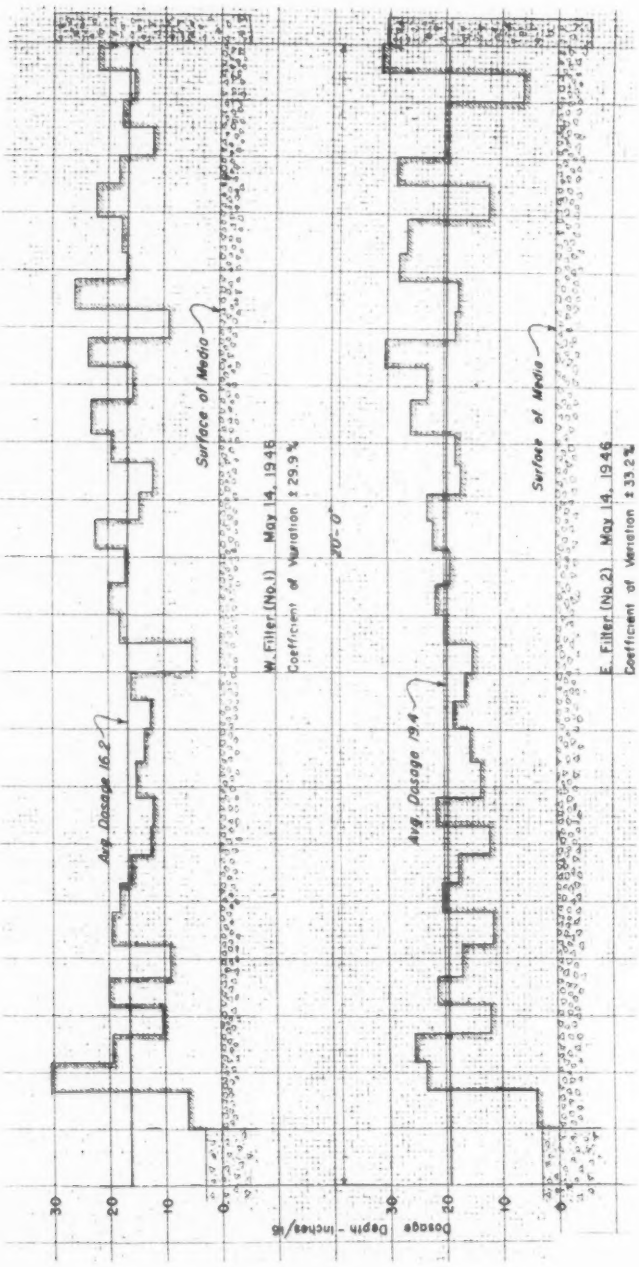

FIGURE 5.—Filter dosage distribution in series operation.

Coefficient of Area is the ratio of the filter surface receiving sewage to the total filter area.

Coefficient of Distribution is an empirical evaluation of the uniformity of dosing by a single term. According to Walton, it is computed by adding the percentage of filter areas on which the flow deviation exceeds 100 per cent, 75 per cent, 50 per cent, 25 per cent and 0 per cent and dividing the sum by 100.

Dosing Ratio is the maximum depth applied on any unit area during the test divided by the mean depth for that test.

The coefficient of area indicates that 99.5 per cent of these filter areas were being dosed both during parallel and series operation. The coefficient of distribution was very similar for the two filters and also very similar during parallel operation at a 325-g.p.m. dosing rate and during series operation at a 650-g.p.m. dosing rate. A comparison of the coefficient of distribution and dosing ratio obtained here with those obtained at Neosho, Mo. (4), follows:

	Neosho		Elizabethtown (Conv.)	
	Aero-filter	Conventional	Filter No. 1	Filter No. 2
Dosing Rate (g.p.m.)	1200	1200	650	650
Dosing Rate (m.g.a.d.)	32.8	32.8	32.5	32.5
Coef. of Distribution	1.46	1.68	1.54	1.56
Dosing Ratio	1.82	1.54	1.88	1.62

These data indicate that the distribution obtained at Elizabethtown compares favorably with that obtained on the aerofilter at Neosho, Mo.

Charts have been prepared showing the variations in dosage on the two filters, both under parallel and series operation, and are presented as Figures 4 and 5.

A salt detention test was made on the filters operating in series and the dispersion curves are shown in Figure 6. The time curve shown is after the addition of the salt to the influent of the first filter. A portion of

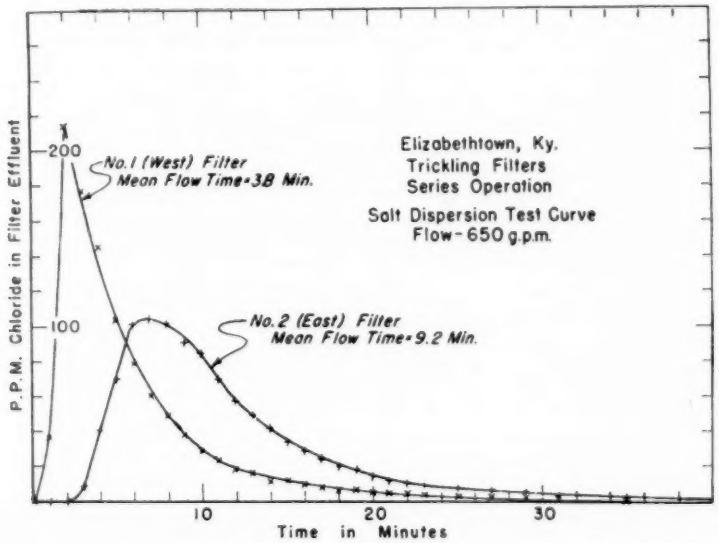

FIGURE 6.—Salt dispersion test curves for filters in series operation.

the lag between the salt peaks is undoubtedly due to the capacity of the pump suction pit between the filters.

Collection of Samples

Samples were collected every half hour of the raw sewage, and of the primary, both filter and final effluents. In addition to these samples, when the operator was pumping sludge to the digester, samples were collected every 10 min. from the digester overflow. Inasmuch as final effluent was recirculated, it was not necessary to collect a sample of the recirculated effluent. Samples were collected over a 24-hour period and stored in an ice box until brought to the laboratory for analysis. No attempt was made in the collection of samples to allow for detention time in any of the plant units. In addition to the samples enumerated above, dissolved oxygen determinations were made throughout the plant at various times.

Analytical Procedures

The analytical methods used were in the most part those given in "Standard Methods" (5). In the determination of dissolved oxygen, the copper sulfate-sulfamic acid inhibitor was used as recommended by Ruchhoft and Placak (6). In addition to this modified procedure, the Kjeldahl nitrogens were run by a semimicro method developed by Robert C. Hamilton, superintendent of the plant.

Analytical Results

As stated previously, the study at Elizabethtown was divided into three periods. During the first period the plant was operated normally with the filters in parallel. In the second period the proportion of final effluent recirculated was increased, with the filters still in parallel operation. During the third period the amount of recirculation was cut down and the filters were operated in series.

TABLE IV.—B.O.D. and pH Data

	5-Day B.O.D. (p.p.m.)						pH					
	Raw Sewage	Prim. Effl.	Filter Effluents		Final Effl.	Digester Supernatant	Raw Sewage	Prim. Effl.	Filter Effluents		Final Effl.	Digester Supernatant
			No. 1	No. 2					No. 1	No. 2		
First Period—Normal Operation—Filters in Parallel												
Average	351	125	65	71	61	1291	7.3	7.3	7.4	7.4	7.5	7.2
Maximum	448	149	100	91	73	2816	7.4	7.5	7.5	7.5	7.6	7.3
Minimum	210	61	24	31	25	928	7.1	7.0	7.3	7.3	7.4	6.9
Second Period—High Recirculation—Filters in Parallel												
Average	273	85	41	41	31	917	7.3	7.5	7.5	7.5	7.6	7.2
Maximum	361	119	60	68	50	1179	7.5	7.7	7.7	7.5	7.7	7.7
Minimum	158	49	18	18	16	722	7.2	7.3	7.4	7.4	7.5	7.1
Third Period—Filters in Series												
Average	269	85	49	32	24	870	7.3	7.4	7.5	7.5	7.5	7.3
Maximum	358	116	70	43	31	1537	7.4	7.6	7.5	7.6	7.7	7.4
Minimum	199	57	26	23	15	629	7.2	7.3	7.4	7.3	7.5	7.2

TABLE V.—Suspended Solids Data

	Total Suspended Solids (p.p.m.)						Volatile (p.p.m.)					
	Raw Sewage	Prim. Effl.	Filter Effluents		Final Effl.	Digester Supernatant	Raw Sewage	Prim. Effl.	Filter Effluents		Final Effl.	Digester Supernatant
			No. 1	No. 2					No. 1	No. 2		
First Period—Normal Operation—Filters in Parallel												
Average	288	96	73	80	68	1285	241	73	54	61	56	1022
Maximum	402	148	116	146	92	4124	376	132	90	124	86	3260
Minimum	228	40	28	26	40	668	170	38	24	18	26	536
Second Period—High Recirculation—Filters in Parallel												
Average	241	100	86	87	69	998	192	75	62	61	46	786
Maximum	282	134	126	136	120	1280	222	104	100	108	96	948
Minimum	170	70	54	50	42	672	142	56	36	36	28	568
Third Period—Filters in Series												
Average	209	96	82	76	54	3346	152	59	49	45	35	2330
Maximum	328	118	116	98	78	11460	242	88	84	60	56	7570
Minimum	116	56	48	60	20	876	82	50	30	32	16	628

In Tables IV to VII, are given the basic analytical results obtained during the study. Table IV shows the B.O.D. and pH data collected in the three periods of the study. In this and the following tables the data obtained for each of the three periods of operation were summarized and averaged separately. It will be noted (Table IV) that the average 5-day B.O.D. of the raw sewage varied from 351 p.p.m. for the first period to about 270 p.p.m. for the second and third periods. The mean suspended solids values (Table V) also show some decrease, from 288 p.p.m. in the first period to 241 and 209 p.p.m. in the second and third periods, respectively. The explanation for this reduction in B.O.D. and suspended solids of the raw sewage is undoubtedly the fact that more rain fell during the second and third periods of study with subsequently more infiltration.

An examination of Table IV indicates a reduction in 5-day B.O.D. from 351 p.p.m. for the raw sewage to 125 p.p.m. for the primary effluent in the first period, and similar reductions from 270 to 85 p.p.m. in the primary tank for the second and third periods. This represents a reduction in B.O.D. of more than 60 per cent in the primary tank, which is the result of the introduction of final effluent into the raw sewage for recirculation through the primary tank and filter.

During the periods of parallel operation of the filters, the effluents from the two filters showed about the same concentration of B.O.D., averaging 65 and 71 p.p.m. for the first period and 41 p.p.m. for each filter effluent for the second period. When the two filters were operated in series in the third period, the average B.O.D. of the first filter effluent was 49 p.p.m. and this was further reduced to 32 p.p.m. on passage through the second filter. The final effluent showed a further reduction of about 10 p.p.m. for each period as a result of settling in the final tank.

The average B.O.D. of the final

effluent under normal operation (first period), with a recirculation ratio of 0.69, was 61 p.p.m. During the second period, when the average recirculation ratio was increased to 0.90, the average final effluent B.O.D. was 31 p.p.m. This shows a very considerable improvement in effluent B.O.D. as a result of the reduction in raw sewage strength and increased rate of recirculation. During the third period, with a recirculation ratio of 0.63 and the two filters in series, the B.O.D. of the final effluent was further reduced to an average of 24 p.p.m. These final effluent B.O.D. values of 61 to 24 for the various periods illustrate the flexibility of this plant in handling a load and producing the kind of effluent needed depending upon the flow of the stream into which the effluent is discharged.

The pH values for the various sampling points for the three periods are also shown in Table IV. These data indicate normal progressive pH changes from about 7.3 for the raw sewage to 7.5 for the final effluent for all periods of operation.

The mean suspended solids values for the raw sewage and primary effluent were 288 and 96, 241 and 100, and 209 and 96 p.p.m., for the first, second, and third periods, respectively. These reductions in suspended solids in the primary tank were influenced by the recirculation of effluent. During parallel operation the suspended solids in the filter effluents averaged 73 and 80 p.p.m. for the first period and 86 and 87 p.p.m. for the second period. During the period of series operation the suspended solids averaged 82 p.p.m. in the first filter effluent and 76 p.p.m. in the second. The plant effluent contained an average of 68, 69, and 54 p.p.m. of suspended solids in the first, second and third periods, respectively. This indicates only 11, 20, and 29 per cent removal of the suspended solids carried in the filter effluents by the secondary tank. These poor removals suggest rather poor performance for the secondary tank, which seems to be largely responsible for the rather high suspended solids content of the final effluent.

The ammonia, Kjeldahl, nitrite and nitrate nitrogen data are given in Table VI. The ammonia nitrogen averaged 20.0, 21.5 and 17.3 p.p.m. and the Kjeldahl nitrogen averaged 39.0, 45.6 and 42.4 p.p.m. in the raw average for the three periods of operation. These values indicate a fairly strong sewage and seem entirely normal. Also, they do not confirm the reduction in sewage strength suggested by the B.O.D. values in the second and third periods. As would be expected, no reduction in ammonia was found as a result of primary treatment. There was, however, an over-all removal of ammonia by the entire plant of 4.3, 4.2 and 5.7 p.p.m., which represented removals of about 21.4, 19.5 and 33.8 per cent in the first, second and third periods, respectively. The over-all removals of Kjeldahl nitrogen by the entire plant were 31.0, 24.6 and 21.8 per cent, respectively, for the three periods. Thus the plant performance on the basis of the ammonia and Kjeldahl nitrogen criteria does not check, but this is not surprising because of the difficulties and variations in these criteria particularly in a short series of tests.

A difference in nitrification was found during the study as a result of the difference in plant operation. The data show that the average nitrite content in the effluent was 0.66, 1.60 and 2.18 p.p.m. for the three periods of operation, respectively. The similar nitrate values were 0.17, 0.55 and 0.98 p.p.m. for these periods. These data indicate improved nitrification for the third period when the two filters were in series, and are in agreement with the results represented by the B.O.D. suspended solids and ammonia data. It is concluded, therefore, that since the Kjeldahl data are not in agreement

TABLE VI.—Nitrogen Data

	Free Ammonia Nitrogen (p.p.m.)						Kjeldahl Nitrogen (p.p.m.)						Nitrite Nitrogen (p.p.m.)			Nitrate Nitrogen (p.p.m.)		
	Raw Sew.	Prim. Effl.	Filter Effluent		Final Effl.	Digester Supernatant	Raw Sew.	Prim. Effl.	Filter Effluent		Final Effl.	Digester Supernatant	Prim. Effl.	Final Effl.	Digester Supernatant	Prim. Effl.	Final Effl.	Digester Supernatant
			No. 1	No. 2					No. 1	No. 2								
First Period—Normal Operation—Filters in Parallel																		
Average	20.0	19.1	17.0	16.9	15.7	118	39.0	30.8	27.0	26.7	26.9	767	0.0	0.66	0.0001	0.01	0.171	0.0
Maximum	25.0	25.0	22.0	22.0	20.0	200	50.5	38.8	30.2	32.0	33.8	1434	0.0	0.9	0.001	0.1	0.6	0.0
Minimum	16.0	15.0	12.0	12.0	12.0	40	29.6	24.2	7.1	18.4	24.4	311	0.0	0.4	0.000	0.0	0.0	0.0
Second Period—High Recirculation—Filters in Parallel																		
Average	21.5	21.5	19.3	18.1	17.3	152	45.6	39.7	36.6	35.2	34.3	695	0.014	1.60	0.015	0.004	0.55	0.004
Maximum	28.0	25.0	25.0	23.0	23.0	170	77.7	53.5	50.0	50.0	42.3	1460	0.10	3.0	0.040	0.03	1.60	0.04
Minimum	14.0	14.0	14.0	12.0	12.0	110	31.2	26.2	30.2	23.4	24.1	199	0.0	0.25	0.0	0.0	0.02	0.0
Third Period—Filters in Series																		
Average	17.3	17.3	15.7	14.7	11.6	138	42.4	40.1	34.3	33.8	33.2	317	0.042	2.18	0.032	0.0	0.98	0.0
Maximum	24.0	22.0	20.0	20.0	17.0	180	61.0	46.1	44.0	40.8	40.8	887	0.35	3.00	0.050	0.0	2.4	0.0
Minimum	12.0	12.0	12.0	10.0	5.0	120	32.1	32.2	28.1	26.2	27.6	194	0.003	1.50	0.020	0.0	0.2	0.0

TABLE VII.—Dissolved Oxygen Data

	Raw Sewage		Primary Effluent[1]		Filters[2]				Final Clarified Effl.				Plant Effluent[3]			
					No. 1		No. 2		A.M.		P.M.		A.M.		P.M.	
	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)	Temp. (°C.)	D.O. (p.p.m.)
First Period—Normal Operation—Filters in Parallel																
Average	20.0	3.70	19.5	4.10	19.5	6.20	20.0	5.80	20.0	4.11	19.8	4.52	20.2	5.60	20.0	4.15
Maximum	20.0	3.70	19.5	4.10	19.5	6.20	20.0	5.80	20.5	4.54	20.0	4.90	20.5	6.79	20.0	4.30
Minimum	20.0	3.70	19.5	4.10	19.5	6.20	20.0	5.80	19.5	3.80	19.5	3.75	20.0	4.90	20.0	4.00
Second Period—High Recirculation—Filters in Parallel																
Average	22.5	4.30	21.0	5.69	21.0	6.52	21.0	6.45	19.8	6.60	20.8	6.17	20.2	6.64	20.9	6.87
Maximum	22.5	4.30	21.0	5.69	21.0	6.52	21.0	6.45	21.0	7.50	23.0	7.71	22.0	7.00	23.0	8.16
Minimum	22.5	4.30	21.0	5.69	21.0	6.52	21.0	6.45	18.5	5.50	16.5	4.44	17.5	5.30	17.0	3.36
Third Period—Filters in Series																
Average	21.3	2.65	20.8	3.56	21.0	6.97	21.0	6.26	20.3	6.68	21.3	5.75	20.3	7.41	21.3	7.04
Maximum	22.5	4.49	21.5	7.90	22.0	9.70	22.0	7.98	23.0	8.13	23.0	7.63	23.0	9.33	22.5	8.65
Minimum	20.0	0.78	20.5	1.87	20.5	4.63	21.0	5.39	19.0	4.20	19.5	4.25	18.5	4.91	20.0	5.45

[1] Samples from distributor box.
[2] Samples caught in pans at level of filter stones.
[3] Sample taken at outfall to stream.

TABLE VIII.—Plant Loadings in Pounds of B.O.D. and Suspended Solids

	(A) Raw Sewage[1]		(B) Digester Supernatant		(C) Recirculated Effluent		Primary Influent (A+B+C)		Primary Effluent		Filter Effluents				Final Effluent	
											No. 1		No. 2			
	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids
First Period—Normal Operation—Filters in Parallel																
Average	1575	1293	167	172	191	217	1933	1685	972	748	251	283	274	298	471	534
Maximum	1914	1828	376	551	246	286	2291	2247	1160	1152	389	452	354	483	508	716
Minimum	1411	971	124	84	88	83	1119	1356	471	312	92	125	119	101	194	216
Second Period—High Recirculation—Filters in Parallel																
Average	1092	958	120	132	116	254	1328	1344	663	784	159	334	160	337	242	538
Maximum	1564	1231	148	171	168	399	1863	1696	926	1043	234	491	263	529	392	934
Minimum	570	612	96	90	66	147	742	967	379	545	70	156	71	195	127	328
Third Period—Filters in Series																
Average	1408	1061	139	261	61	134	1584	1412	663	745	378	639	249	593	186	417
Maximum	1530	1691	192	658	100	237	2066	1995	903	919	546	903	334	763	240	607
Minimum	958	675	45	57	11	20	1140	695	446	436	201	374	181	467	113	156

[1] Raw sewage corrected for digester supernatant.

with the other important criteria, the Kjeldahl data are probably in error.

Dissolved Oxygen Data

The dissolved oxygen was determined at various times at all of the common sampling points in the plant (Table VII). The raw sewage at this plant was relatively fresh and contained between 0.78 and 4.3 p.p.m. of dissolved oxygen. The plant effluent contained an average of 4.9, 6.7 and 7.2 p.p.m. of dissolved oxygen for the three periods of operation, and showed an increase of 1.2, 2.4 and 4.6 p.p.m. over the dissolved oxygen in the raw sewage. These data again show the advantage of the higher recirculation ratio and of the operation of the filters in series.

Plant Loadings and Performance

From the sewage flow and analytical data the quantity of B.O.D. and suspended solids in the flows at the various sampling points were calculated and are given in Table VIII. From these data the primary, secondary and over-all plant efficiencies were calculated and are presented in Table IX.

Filter Performance

The calculated values of B.O.D. and suspended solids applied to the filter per cubic yard of filter volume and the removal efficiencies are given in Table X. As an attempt was made to divide the primary effluent flow equally in the division box, it was assumed that the same load was applied to each filter during the two periods when

TABLE IX.—Per Cent Removals of B.O.D. and Suspended Solids

	Primary Treatment[1]		Filters[1]				Final Clarifier[1]		Secondary Treatment		Entire Plant[2]	
			No. 1[3]		No. 2							
	B.O.D.	Suspended Solids	B.O.D.	Suspended Solids	B.O.D.	Suspended Solids	B.O.D.	Suspended Solids	B.O.D.	Suspended Solids	B.O.D.	Suspended Solids
First Period—Normal Operation—Filters in Parallel												
Average	49.3	53.2	46.3	16.7	—	—	9.1	− .84	51.5	25.9	75.5	67.3
Maximum	63.1	81.2	55.2	78.4	—	—	20.2	45.1	58.8	59.4	79.2	86.9
Minimum	35.6	24.9	27.2	−38.2	—	—	−11.6	−88.4	39.4	− 9.5	71.5	55.5
Second Period—High Recirculation—Filters in Parallel												
Average	49.5	41.2	52.8	11.7	—	—	20.9	18.1	63.5	29.8	81.8	60.1
Maximum	60.8	59.2	63.9	35.6	—	—	33.0	40.0	73.4	47.7	89.0	73.3
Minimum	39.1	24.4	31.0	−39.5	—	—	− 2.3	−15.1	46.4	− 7.1	77.9	44.9
Third Period—Filters in Series												
Average	57.8	46.4	43.1	14.9	33.7	5.8	19.6	30.2	71.8	44.3	88.2	70.6
Maximum	74.2	63.6	57.4	28.9	44.9	22.5	40.5	66.6	78.9	72.2	93.5	85.1
Minimum	43.7	24.9	14.0	− 5.5	5.5	−24.9	− 5.0	−11.4	64.5	22.8	85.2	59.5

[1] Per cent efficiency $= \frac{100 \times \text{lb. removed}}{\text{lb. applied to unit}}$.

[2] Per cent removal $= \frac{100 \times \text{lb. removed}}{\text{lb. applied to plant}}$.

[3] For first and second periods, the "removal efficiency" of both filters in parallel is entered under "Filter No. 1."

TABLE X.—Filter Loadings and Efficiencies
(Loading in Pounds per Cubic Yard of Media; Efficiency as Per Cent Removed)

	Biochemical Oxygen Demand				Suspended Solids			
	Filter No. 1		Filter No. 2		Filter No. 1		Filter No. 2	
	Loading	Efficiency	Loading	Efficiency	Loading	Efficiency	Loading	Efficiency
First Period—Normal Operation—Filters in Parallel								
Average	3.49	48.4	3.49	43.6	2.68	24.3	2.68	20.1
Maximum	4.16	60.9	4.16	54.1	4.13	81.1	4.13	75.5
Minimum	1.69	31.5	1.69	23.0	1.12	−37.9	1.12	−44.6
Second Period—High Recirculation—Filters in Parallel								
Average	2.38	52.1	2.38	51.7	2.79	14.0	2.79	13.3
Maximum	3.32	63.7	3.32	63.7	3.74	42.9	3.35	33.6
Minimum	1.36	34.9	1.36	26.7	1.96	−16.0	1.96	−21.4
Third Period—Filters in Series								
Average	4.83	42.9	2.76	33.0	5.35	14.4	4.58	7.0
Maximum	6.48	57.4	3.92	44.9	6.60	29.0	6.48	22.4
Minimum	3.20	14.0	1.44	5.6	3.12	− 5.7	2.68	−25.0

they were operated in parallel. Table X indicates that there was considerable variation from day to day both in B.O.D. and suspended solids load during each period of operation. The average load per cubic yard was 3.49 lb. of B.O.D. during the first period and this was decreased, by by-passing, to an average of 2.38 lb. in the second period. With the filters in series in the third period, the first filter received the very high average load of 4.83 lb. of B.O.D. and the second filter an average of 2.76 lb. of B.O.D. per cubic yard. These data, therefore, give some interesting information with respect to B.O.D. and suspended solids removals of shallow filters for a wide range of filter loadings. The values for maximum, minimum and mean quantities of B.O.D. removed by the filters alone in pounds per cubic yard were as follows:

Filter No.	First Period; Parallel; Recirculation Ratio = 0.69			Second Period; Parallel; Recirculation Ratio = 0.90			Third Period; Series; Recirculation Ratio = 0.63		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1	2.29	1.04	1.69	1.68	0.86	1.24	3.17	0.64	1.98
2	2.08	0.76	1.52	1.82	0.69	1.23	1.59	0.43[1]	0.91

[1] Excluding one result which showed the removal of only 0.08 lb. of B.O.D. per cubic yard.

The quantities of suspended solids removed by the filters alone in pounds per cubic yard is shown in table at top of page 48.

These data indicate that the filters have a greater variability in suspended solids removal than in B.O.D. removal, regardless of loading or method of operation.

Filter No.	First Period; Parallel			Second Period; Parallel			Third Period; Series		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1	3.35	0.11	0.65	1.07	0.34	0.55	1.69	−0.23	0.76
2	3.12	0.0	0.54	0.84	−0.67	0.37	1.00	−0.67	0.33

The relation between B.O.D. loading and B.O.D. removal is shown in Figure 7. These data show a rather consistent relationship between the filter load and B.O.D. removal for all the loadings of the first filters receiving primary sewage. It is indicated that this relationship can be represented by a straight line as shown, and there seems to be no definite indication of reduction in removal as the load was increased to the 5 to 6 lb. per cu. yd. loading range. On the basis of this curve the percentage of B.O.D. removal should fall only from about 52 to 47 per cent as the load is increased from 2 to 6 lb. per cu. yd. on the first filter.

It will also be noted that there was no difference between the load and B.O.D. removal relationship during the first and second periods of operation. This suggests that the increase in the recirculation ratio from 0.69 to 0.90 from the first to the second period had little effect on the relationship of B.O.D. removed to load. The increased percentage of B.O.D. removal during the second period was largely the result of the reduced load, and was not the result of the increased recirculation. The data plotted for Filter No. 2 in the third period, when the filters were in series, follows the broken line curve and shows definitely that the secondary filter has a different B.O.D. removal to load relationship and gives a lower percentage of B.O.D. removal at all loads than the primary filters.

It is interesting to compare the performance of the filter alone at Eliza-

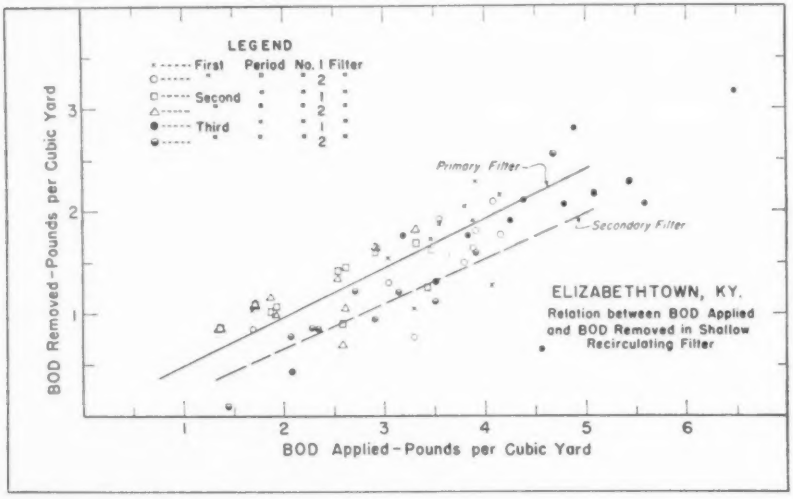

FIGURE 7.—Relation between B.O.D. applied and B.O.D. removed.

bethtown with the performance of two shallow recirculating military sewage filters (6). The comparative data are as follows:

Plant	Depth (ft.)	Recirculation Ratio	B.O.D. Loading			B.O.D. Performance		
			Applied (p.p.m.)	Lb. per Acre-Ft. per Day	Lb. per Acre per Day	Eff. (p.p.m.)	Lb. per Acre-Ft. Removed	Efficiency (%)
Fort Bragg	3.42	4.15	109	4,340	14,900	70	2,745	63.3
E-town 1st P.	3.0	0.69	125	5,640	16,900	65	2,600	46.0
E-town 2nd P.	3.0	0.90	85	3,840	11,520	41	2,000	51.9
E-town 3rd P.	6.00	0.63	85	3,840	23,100	32	2,400	64.0
Fort Dix	3.75	2.82	93	2,320	8,720	54	1,250	53.9

These data indicate that considering the much lower recirculating ratios the Elizabethtown filter compared favorably with the performance obtained in similar but slightly deeper filters at Fort Bragg and Fort Dix. It should also be noted that the size of the filter media at these two army plants was 1½ to 2½ in. compared to 2 to 3 in. at Elizabethtown.

Over-all Plant Efficiency

In Table IX is also given the over-all plant efficiency for the three periods studied. It will be noted that with normal operation, only 75.5 and 67.3 per cent of the B.O.D. and suspended solids, respectively, were removed. This is especially low removal of suspended solids, and is doubtless due to poor performance of the final clarifier.

With decreased load and increased recirculation of final effluent in the second period the per cent removals of B.O.D. and suspended solids were 81.8 and 60.1. As indicated in Figure 7 most of the improvement in performance in the second period seems to be due to the decreased sewage load. Because the suspended solids removal was lower in the primary tank during the second period, a lower over-all plant efficiency of 60.1 per cent was obtained.

The effect of operating the filters in series is shown during the third period when the plant load was approximately the same as in the first period and no raw sewage was being bypassed. An over-all removal of 88.2 per cent of the B.O.D. and 70.6 per cent of the suspended solids was obtained. This is a decided improvement in B.O.D. removal over that obtained in the first period.

Conclusions

1. The primary tank performed satisfactorily throughout the study and gave an average of about 50 per cent B.O.D. removal and 47 per cent suspended solids removal.

2. Normal operation with the two filters in parallel gave a poorer plant effluent than operation with the two filters in series.

3. The two filters had good sewage distribution and gave excellent B.O.D. removals for shallow filters with low recirculation ratios.

4. The B.O.D. filter loading range in pounds per cubic yard of filter volume varied from 1.36 to 6.48 during this study; there was no evidence of a break in the straight line relationship between the B.O.D. loadings and removals.

5. The rather poor efficiencies of the secondary treatment was due to poor performance of the secondary tank and not to poor filter performance.

6. The higher recirculation ratios needed with parallel filter operation to produce the quality of effluent needed at Elizabethtown cannot be ob-

tained due to plant hydraulic and pumping limitations.

7. The high volumetric sewage load applied to the filters during series operation was not detrimental during the study.

8. The best over-all filter efficiency and plant performance with the filters in series gave an average over-all B.O.D. removal of 88 per cent and a plant effluent with a B.O.D. of 24 p.p.m.

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WATER AND SEWAGE GLOSSARY AVAILABLE SOON

Advance orders are now being taken for late spring delivery of the GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING. The Glossary has been prepared by a joint committee representing the Federation of Sewage Works Associations, the American Society of Civil Engineers, the American Water Works Association, and the American Public Health Association. It contains more than 2,600 terms pertaining to the nomenclature of the hydrologic, hydraulic, water and sewage works engineering fields. Thoroughly reviewed by practicing engineers, specialists in specific fields, and representatives of educational institutions and governmental agencies, the Glossary is a definitive work on hydraulic and sanitary engineering nomenclature.

Price of the Glossary to all members of the Federation's constituent associations is $1.00 (paper cover). Advance orders, with check or money order, should be sent to the Federation's Headquarters Office, 325 Illinois Bldg., Champaign, Illinois.

Since only a limited edition of the Glossary is now planned, Federation members are advised to place their advance orders as early as possible. Delivery of the Glossary will be made as soon as copies are received from the printer, probably by late spring. Nonmembers may order copies of the Glossary directly from the American Society of Civil Engineers, 33 West 39th Street, New York 18, N. Y. The price to non-members is $2.00 (paper cover).

Industrial Wastes

STREAM POLLUTION CONTROL ACTIVITIES OF INDUSTRIAL ASSOCIATIONS *

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The magnitude of any industrial problem, regardless of its character, may be fairly measured by the attention it is receiving in the trade and professional organizations that purport to serve the particular industry. The elimination and prevention of stream pollution caused by industrial wastes is admittedly a major problem of the day, and it is the purpose of this paper to survey the activities of industrial organizations that are presently directed toward that aim.

This "barometer reading" is documented by direct correspondence with officials of 23 trade associations, professional organizations, institutes and foundations representing 15 major industries. Every organization was approached that is known at one time or another to have been interested in waste disposal. Failure here to mention any pertinent work is purely unintentional, and will gladly be acknowledged in a supplement to this paper.

The original intention to confine the survey to so-called "trade" associations was abandoned when a rather wide variety of professional groups, research foundations, special commissions—and even one state agency—were found to be involved along with certain trade associations. Only organizations whose interests are restricted to a specific industry are included, not technical societies such as the Federation of Sewage Works Associations, American Chemical Society, American Institute of Chemical Engineers and others, who are concerned with the broader aspects of stream pollution from all sources. Neither is coverage included of such bodies as the Pennsylvania Chamber of Commerce, the Cincinnati Chamber of Commerce and others, which are performing sterling service in the encouragement of pollution abatement, whether it be municipal, institutional or industrial in origin.

It is realized that many industrial concerns are undertaking their own pollution abatement programs, without depending entirely upon their industry associations for guidance. General Motors, Atlantic Refining, Ford, Du Pont, American Viscose, and American Cyanamid are just a few examples of such individual company activity. Discussion of these functions is also beyond the scope of this study.

The survey sought to gather information on past, current and planned accomplishments of industry associations in the way of pollution abatement, how they are going about it, and when they began. The results are presented according to the industry served.

Brewing Industry

Through its Research Committee, the *United States Brewers Foundation, Inc.* (1) is financing a research project at Purdue University on the utiliza-

* Presented at 20th Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn., State College, Pa., August 26, 1948.

tion and disposal of brewery waste products. The project was initiated in 1946 by the *Indiana Brewers Association* and was continued in operation for the first two years by that organization.

The first year's work was devoted to the development of a comprehensive bibliography, the analysis of typical waste samples to determine their strengths and characteristics, and to some laboratory studies. A method was reported for reducing the dissolved solids and B.O.D. of press liquors by inoculation with bakers' yeast, with a concurrent increase in yeast. In 1947 principal attention was given to the utilization of spent hops by composting for use as fertilizer.

Further research is continuing along similar lines.

Canning Industry

Fruit and Vegetable Canning

The utilization and disposal of fruit and vegetable cannery wastes has been given attention by the *National Canners Association* (2) for more than a decade. Several important contributions have derived from this agency.

Waste prevention and disposal activities are under the general guidance of the Scientific Research Committee, and are conducted by the Sanitation Department of the association's Research Laboratories. A staff of three sanitary engineers is engaged on waste disposal studies.

The Sanitation Department of the association endeavors to fulfill its objective—the assistance of canners in accomplishing practical solutions to waste disposal problems—by (*a*) independent research, (*b*) cooperative research, (*c*) advisory consultation services to individual canners, and (*d*) a program of industry education.

Two noteworthy bulletins have been published on cooperative research studies with the Wisconsin Canners Association and the Wisconsin State Board of Health: "Methods of Treating Cannery Waste" in 1939, and "Cannery Waste Disposal Lagoons" in 1945. Many other pertinent articles have been authored for trade periodicals by the Sanitation Department staff, and have been made available as reprints to members of the association as part of the industry educational program.

Present plans include cooperative research projects with Purdue University, the Wisconsin State Board of Health, and at least one other agency. Independent work in the Research Laboratories of the association is to be done on (*a*) methods of treatment for apple cannery wastes, (*b*) modifications of the standard B.O.D. determination, and (*c*) methods of preserving samples for B.O.D. determination.

A regional organization, the *Tri-State Packers Association* (3), *Inc.*, is showing some interest in stream pollution. This is a trade association serving packers engaged in canning and freezing of fruits, vegetables, seafoods and specialty items in the states of Delaware, Maryland and New Jersey.

Joint meetings have been held with the Maryland State Water Commission for the purpose of acquainting the association's members with pollution control laws and regulatory policies. Further efforts are planned toward industry education along the lines of practical pollution control.

State associations of canners in Wisconsin, California, Indiana, Minnesota and New York have also been active to a varying degree, usually in cooperation with the national organization.

Citrus Fruit Canning

Although it is a state agency, established to administer state laws governing the citrus industry, the *Florida Citrus Commission* (4) is included here as an industrial organization. The interests of the Commission are re-

stricted specifically to the one industry, and its functions in many respects are parallel to those of a trade association.

The Commission consists of eleven citrus growers, four of whom are also shippers or are associated with an organization concerned with shipping, packing or marketing. A Research Department is provided for, to function under a research director. One basic purpose of the Commission is to conduct "comprehensive study and research (preferably at the University of Florida) to determine all possible new and further uses for citrus fruits —and the products and by-products into which the same can be converted or manufactured. . . ." It is under this provision that concern with by-product recovery and waste disposal is justified.

Independent and cooperative research with the U. S. Citrus Products Station at Winter Haven, Fla., has been productive of several practical contributions. The peel and seeds from juicing operations were found to be an excellent cattle feed after pressing and drying; press liquors, formerly wasted, were found possible of concentration into citrus molasses. Studies of feed yeast production from such press liquors are also promising. Treatment of other liquid wastes on trickling filters has been found effective, though expensive.

At this time anaerobic fermentation studies are under way on a pilot plant scale.

The Commission's appropriations for waste studies have averaged about $12,000 annually in recent years.

Fish Canning

The *California Fish Canners Association, Inc.* (5), has rendered certain of its member companies a unique service by acting as the medium through which a cooperative abatement project was actually constructed.

A standing Harbor Water and Sewer Committee is comprised of top officials of all canners involved in the waste disposal problem. Its objective is to "design and construct collectively and individually those installations necessary to effect waste disposal and eliminate contaminated water."

In at least one instance, this committee brought about the "installation of a new and adequate pumping plant and waste collection system, which will be operated by the Harbor Department for the canners, and the installation of chlorination equipment at each cannery to purify the harbor water used in the cannery. . . ." One member of the committee was assigned the responsibility of employing a consulting engineer and supervising prosecution of the work.

The committee is presently cooperating with a special commission of the California Legislature in the preparation of waste control and disposal legislation.

Chemical Manufacturing Industry

In the broad field of chemical manufacture, the *Manufacturing Chemists' Association of the United States* (6) has undertaken a sizeable task in its aim to assist its member companies in the solution of waste prevention and disposal problems. An impressive and promising beginning has been made.

A standing Stream Pollution Abatement Committee was created a few years ago, on which ten technical representatives of chemical manufacturing companies are serving. The specific aims of the committee are:

(*a*) To acquaint the industry with the nature of stream pollution.

(*b*) To provide opportunity for the exchange of technical information on waste treatment.

(*c*) To direct attention to the possibilities of production process changes as a means of reducing pollution.

(*d*) To encourage cooperation of the pollution regulatory bodies.

(*e*) To assist individual companies to organize for sound and effective abatement programs.

(*f*) To keep the industry posted on present laws and trends in pollution control legislation and regulation.

It will be noted that these aims are largely directed toward industry education and encouragement of the interchange of technical information.

The Stream Pollution Abatement Committee has met several times yearly since its inception. In 1947 and 1948 it sponsored 2-day conferences attended by representatives of the Association's member companies. Legal, public relations and technical aspects of the stream pollution problem drew major attention at the 1947 meeting. At the 1948 gathering 84 company representatives exchanged technical data on the treatment and disposal of chemical wastes.

The Committee has made a unique contribution in its Manual Sheet W-1, "Organization and Method for Investigating Wastes in Relation to Water Pollution," published in 1948. This bulletin outlines the approach and detailed procedure for the analysis of industrial waste problems. Other accomplishments are the distribution of a comprehensive bibliography on chemical wastes, as compiled by Chairman R. W. Hess, and the collection of data on types of problems, expenditures and programs of the industry related to pollution abatement.

Activities of the committee are presently being expanded by the creation of sub-committees which will function under the following classifications: inorganic acids and alkaline wastes; insoluble and undissolved substances; soluble inorganic salts; soluble organic substances; tars and oily substances. The program also contemplates strengthening liaison with other organizations concerned with the problem, and the encouragement of institutional research fellowships.

Dairy Industry

The dairy industry as a whole is made up of several segments representing various milk products and methods of processing, all of which are related in the sense that their waste disposal problems are similar. The trade associations of seven of these segments logically have joined forces to solve these problems through the *Task Committee on Dairy Waste Disposal* (7), created in 1946. The participating organizations are the *National Cheese Institute, American Butter Institute, Evaporated Milk Association, International Association of Ice Cream Manufacturers, American Dry Milk Institute, Dairy Industry Supply Association,* and *the Milk Industry Foundation.*

The program of the committee includes:

(*a*) Industry education on ways and means of reducing dairy wastes.

(*b*) Studies of equipment design and plant layout to minimize wastes.

(*c*) Studies of economical methods of waste utilization.

(*d*) Industry education on the importance of measurement and analysis of plant wastes.

(*e*) Collection, evaluation and dissemination of information regarding waste treatment methods and their economics.

Full cooperation with the activities of state pollution control agencies, as is presently occurring in Pennsylvania, is contemplated in the attainment of these objectives.

In 1946 the committee issued a bulletin entitled "Dairy Waste Saving and Disposal," that has been widely reprinted in industry periodicals. Members of the committee have contributed numerous papers and articles to trade association meetings and publications, all aimed at the education of plant management on the necessity of waste prevention. These efforts have been deemed highly successful.

Two cooperative research projects are being sponsored by the committee. The first of these, involving a tentative cost of $10,095, has been established at Michigan State College. Equipment is now being installed in a pilot plant at a milk processing station near the college. The efficiency and economics of the aerated holding tank followed by biological filtration will receive first attention, followed by other studies.

The second project is in operation at the Eastern Regional Research Laboratory (Philadelphia) of the U. S. Department of Agriculture. A 3-year program costing $15,000 annually will encompass laboratory studies of the destruction of milk solids by (*a*) aeration in the absence of biological life, (*b*) oxidizing agents, (*c*) aerobic fermentation, and (*d*) anaerobic fermentation; of the influence of temperature, acidity and other factors upon aerobic fermentation cultures; and of simplified analytical methods that will yield equivalent information to that afforded by the present B.O.D. test.

A bulletin "Waste Prevention in the Dairy Industry" is now in preparation by Prof. E. F. Eldridge of Michigan State College in cooperation with the committee. It will be published by the Michigan Experiment Station.

Electroplating Industry

Another industry organization that has only recently given important attention to the waste recovery and disposal problem is the *American Electroplater's Society* (8), "an educational society for the advancement of the science of electroplating." This body in 1947 established AES Research Project No. 10—The Disposal of Plating Room Wastes, to be directed by a special sub-committee of the society's Research Committee.

The project is in the form of a fellowship at Yale University, and is financed by dues received from sustaining members. The present annual budget is about $2,500.

The objectives of the project are: (*a*) to study the composition, volumes and effects on streams aquatic life and sewage treatment plants of electroplating and related wastes, (*b*) to study methods of recovery of valuable constituents, and (*c*) to study methods of treatment and disposal of residual wastes. The research will take into account the various sizes of plating establishments, the many types of plating that are employed, and the economics of all promising procedures. Preliminary phases of the research include a survey of the literature and a critical review of promising treatment processes; these steps are to be followed by laboratory investigations, pilot plant studies, and cooperative work in industrial treatment plants.

An extensive bibliography on plating wastes has been compiled, and will be published in 1948 in the society's journal, *Plating*. A critical review of the literature on cyanide wastes is nearing completion. Laboratory studies have begun, but have not as yet progressed beyond an assay of analytical methods.

Also under way is a questionnaire survey of 300 electroplating companies, which is expected to yield valuable data on the nature of wastes and present methods of treatment and disposal. A third of these companies have already responded.

Cyanide wastes are to be given the first detailed attention, followed by copper, chromium and others. Due consideration is to be accorded to the various combinations of wastes that occur in practice. Of further significance is the plan to investigate limits of tolerance of these generally toxic wastes in receiving streams.

Gas Industry

The present widespread distribution of natural gas across the nation has relegated most manufactured gas

plants to emergency standby service, thus eliminating gas plant waste disposal as a major stream pollution factor. The *American Gas Association* (9), however, was one of the earliest industrial organizations to attack the problem on an industry-wide basis.

Through its Committee on Disposal of Waste from Gas Plants, the association issued seven reports during the period of 1919–30. All were published in the AGA *Proceedings*. Other special reports were published for the Subcommittee on Water Gas Tar Emulsions, Their Prevention, Treatment and Utilization (1927), and the Subcommittee on Water Gas Tar Production (1928).

The Technical Section of the association, under which the above committees function, is not currently active in studies related to stream pollution prevention. According to Secretary A. Gordon King, however, the Section is aware of state and national trends toward pollution control, and is prepared to act in the event of any demand in the industry for revival of the association's original program.

Meat Packing Industry

This important industry, responsible for numerous cases of stream pollution, both directly and through interference with municipal sewage treatment plants, is according only casual attention in its trade associations to its waste disposal problems.

The *American Meat Institute* (10) has taken no formal action; all inquiries from packers are handled on an individual basis by the Institute's Director of Packinghouse Practice and Research. His office endeavors to keep informed as to waste disposal practice in the industry, and serves as a clearing agency for such information.

This limited activity is mentioned here only because it is typical of the present attitude of too many other industry associations. The attention being given the stream pollution problem is not nearly commensurate with the importance of the issue.

Petroleum Industry

Initiated in 1921, the stream pollution abatement activities of the *American Petroleum Institute* (11) are antedated only by one other industry association. The Oil-Pollution Committee, created in that year, directed its efforts until 1927 to the prevention of oil discharge from ships.

In 1927 the committee made a comprehensive survey of industry pollution problems, securing data from 177 oil fields and 619 processing plants. Among the recommendations for remedial measures that resulted from this survey was one providing for a Technical Committee on Prevention of Pollution. By 1929, a tentative code of good practice was developed, covering all types of industry operations.

Reorganization of all Institute committee activities in 1930 led to the establishment of the three present committees on waste disposal.

The Committee on Disposal of Marketing Wastes published its code of practice in 1933. This problem has apparently been solved for the present.

The Committee on Disposal of Production Wastes has not been so fortunate. Eleven years of effort (1930–41) failed to bring forth a code of practice which was wholly acceptable under varying conditions in the 22 oil-producing states. Since 1941 this committee has functioned only in advisory capacity.

The Committee on Disposal of Refinery Wastes has made three commendable contributions. Section I of its report on "Waste Water Containing Oil" (third edition, 1941) is at present the best known guide for handling oily wastes. Section II deals with "Waste Gases, Vapors, Sludges and Dusts" (third edition, 1948) and Section III with "Waste Water Containing Solutes" (first edition, 1935).

The committee is now engaged in bringing Sections I and III up to date.

Special research is being sponsored by the Institute at Ohio State University and Pennsylvania State College, where methods of measuring toxicity of industrial wastes to bacteria and plankton are being investigated. Consideration is being given to a new research project involving studies of the factors governing the gravity separation of oil from waste water.

The *Pennsylvania Crude Oil Association* has recently undertaken representation of oil producers in that state in discussions with the State Sanitary Water Board. The conferences are aimed toward development of practical requirements for waste disposal incident to the drilling and operation of oil wells.

Pulp and Paper Industry

In the intensity, vigor and scope of its stream pollution abatement program, as manifested by the activities of the *National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries), Inc.* (12), the pulp and paper industry is far ahead of any other. The Council was formed in 1944 by a group of companies representing more than 75 per cent of the entire industry; in 4 years it has grown to 184 member-companies located in 35 states.

This organization was created for the sole purpose of conducting an integrated national program for the abatement of stream pollution resulting from pulp and paper production. An impressive list of fundamental and practical research projects is implemented by direct mill service to apply the laboratory and pilot plant findings to actual mill operations. Industry education is accomplished by regional meetings, and by distribution of newsletters, bulletins and special reports. Of particular importance are the Council's efforts to bring together, for common understanding, agreement on policy, and unity of action, all of the interests that are concerned with stream pollution as related to the pulp and paper industry. These interests include industry management, pollution control and conservation agencies, research organizations, other industries, and water control bodies. Seven regional committees have been set up to assure that all activities are directed toward the varying needs in all parts of the country.

The Council is at present sponsoring cooperative research as follows: Virginia Polytechnic Institute (semi-chemical wastes), Mellon Institute of Industrial research (bleachery wastes and inter-industry problems), Purdue University (strawboard wastes), Rutgers University (white water problems), University of Michigan and Kalamazoo College (deinking wastes), Institute of Paper Chemistry (aquatic biology problems), Manhattan College (stream analysis), Louisiana State University (kraft mill wastes), Oregon State College (yeast production and aquatic biology). Arrangements are in negotiation with Syracuse University for sulfite waste liquor studies.

The magnitude of this work is evidenced by the Council's annual budget of more than $150,000. Twenty technical bulletins were issued in 1946; 44 in 1947. Many other contributions were made to the technical literature.

Before the National Council came into being, the *American Pulp and Paper Association* had a Committee on Stream Pollution. This committee has been discontinued.

Another organization, the *Sulphite Pulp Manufacturers' Research League, Inc.* (13), is currently active in pollution abatement functions. This body has succeeded the Sulphite Pulp Manufacturers Committee on Waste Disposal; it is supported by eleven sulfite pulp producers, whose representatives direct all policy and technical aspects. The objective of the league is to develop economically

practicable methods for eliminating spent sulfite liquor as a factor in stream pollution.

More than $500,000 has been spent to date on studies of waste sulfite liquor treatment by conventional sewage treatment methods, and on searches for potential uses of the material. A plant scale installation for *Torulopsis* yeast production is now being engineered.

The future program of the league includes plans to (*a*) refine the *Torulopsis* yeast process, (*b*) supplement the process with a view toward improved pollution abatement efficiency, and (*c*) search for alternate methods where yeast production is not applicable.

It is understood that the *Technical Association of the Pulp and Paper Industry* (14) is also interested somewhat in stream pollution problems. Detailed information has not been furnished.

Steel Industry

For about 15 years the *American Iron and Steel Institute* (15) has fostered a special committee to correlate the work of the principal steel companies on the proper handling of waste products, from the standpoint of abating stream pollution. Representatives of six large steel producers comprise the present committee.

The objectives of the committee are to study and develop the technical aspects of processes for the treatment and disposal of all industrial wastes of the steel industry, and also to cooperate with federal and state authorities in their efforts to arrive at a feasible degree of purity in receiving lakes and streams.

Since 1938 the Institute committee has sponsored a research fellowship at the Mellon Institute of Industrial Research, at a cost of about $200,000 for the 10-year period. About six of more than fifty proposed methods have been studied critically, and additional development work has been done on five processes. Although several methods are promising from the standpoint of effectiveness, all are expensive, and the present aim is toward practical and adequate processes that will also be economically feasible. Methods of waste reclamation and of by-product recovery are under pilot plant study.

Steel mill wastes are produced in such enormous volumes that the desirability of economical disposal methods is understandable. These wastes are of such significance in the national stream pollution situation, however, that intensification of the Institute's research program appears to be justified.

Tanning Industry

Most of the progress made in waste disposal in the tanning industry may be credited to the organizations serving the industry. Here is a fine example of cooperative effort.

The basic methods of waste disposal now employed throughout the industry resulted from the 6-year investigation of the *Tannery Waste Disposal Committee of Pennsylvania.* This body, composed of representative Pennsylvania tanners with members of the State Sanitary Water Board, was active from 1924 to 1930. Its effectiveness suggests the desirability of similar joint committees of industrialists with pollution control authorities in connection with other industrial waste problems.

The *Tanners Council of America* (16) is the trade association of the industry. In 1924 this body entered into a contract with the University of Cincinnati for the conduct of a general industry program of fundamental research. Three useful reports on waste disposal have derived from the TCA Foundation thus created.

Also an important contributor to tanning waste disposal practice is the *American Leather Chemists Association* (17), which is a technical society

of specialized interest. Its Committee on Stream Pollution was formed in 1938, and has been continued since. Objectives of the committee are to correlate the information available on treatment procedures and to render advisory assistance to members of the association in the solution of individual problems.

The ALCA committee undertook in 1941 a survey of tannery waste treatment plants. These data were compiled and published in the ALCA *Journal* (**38**, 8, August, 1943). A comprehensive abstract of the literature on tannery wastes was then prepared and made available through the same publication (**39**, 10, October, 1944). The committee's present functions consist primarily of advisory services in connection with specific problems that arise in the industry. Broad guidance to the general solution is given; the design and construction of actual treatment facilities is left to the individual company.

Textile Industry

The Textile Foundation, Inc. (18), organized "for scientific and economic research for the benefit and development of the textile industry . . .," undertook from 1932 to 1936 to aid its constituency in problems of waste disposal.

This service began with the fostering of a research fellowship at the University of North Carolina in 1932, when the state board of health found it necessary to suspend studies of textile wastes that had been carried on for several years. Four technical papers came from this research.

In 1935 the Foundation enlisted the aid of a distinguished Advisory Committee on Textile Waste Treatment to make a thorough survey of the literature and of actual waste disposal practice. Leading researchers, industry representatives and stream pollution authorities made up this advisory group.

In cooperation with the University of North Carolina and under the guidance of the advisory committee—with Dr. H. G. Baity as General Adviser—the Foundation published in 1936 the 120-page bulletin "Textile Waste Recovery and Treatment." The report is still the outstanding treatise on textile waste treatment and disposal. Its distribution ended the activities of the Foundation along these lines.

Since 1946 the *Institute of Textile Technology* (19) has concerned itself with waste recovery and disposal problems. The Institute is a non-profit membership corporation, designed to train technicians at the graduate level for work in the textile industry. It is equipped to conduct broad research, and is authorized to grant advanced academic degrees. Financial support comes exclusively from the textile industry.

About $75,000 has been invested in research in the past two years. Biological and chemical studies have been made of all common mill wastes to determine their character and toxic effects in streams. Methods of treatment have been investigated and evaluated from the standpoints of stream standards and recovery products.

Further investigations are planned on kier liquors, bleaching and dyeing wastes, and others involving chemicals, with the intention of recovering certain chemicals for re-use.

Direct mill service is provided by the Institute on a fee basis. Such service would be in the form of sponsored research, directed toward the specific conditions and operations at the particular mill.

Wine Industry

The waste disposal activities of the *Wine Institute* (20), although not national in scope, are of interest. The Institute is a service organization for California wineries, and it has concerned itself with waste disposal during the past two years (1946–48).

These functions center in the Winery Residues Disposal Committee, which considers all proposals for handling residues and recommends those deserving special attention in the way of research.

Two practical bulletins have derived from assignments by the committee to a firm of consultants. Written in lucid, non-technical language, these are entitled "Grape Stillage Disposal by Intermittent Irrigation" (June, 1947), and "Grape Stillage Disposal by Evaporation" (March, 1948).

A search is now being made for recoverable by-products from grape pomace (seeds, skins, pulp and short-stem fibers). No specific program is as yet planned beyond this work.

A total of $15,000 has been expended by the Institute on the 2-year program to date.

Discussion

A striking observation from the survey is that seven of the industry organizations mentioned have initiated their pollution abatement programs within the past two years. Here is proof that the movement in industry to correct stream pollution is now accelerating.

But the list of really active organizations is pitifully incomplete. To the author's knowledge, there are no industry-wide programs in such important industries from a pollution standpoint as coal mining, distilling, rubber manufacturing, wool processing, beet sugar manufacturing, laundering, meat packing, coke production, etc. Moreover, considerable expansion of action appears to be justified in the steel and textile industries, and possibly others.

The combination of related industries for an integrated program, as exemplified by the National Council for Stream Improvement (pulp and paper industry) and the Task Committee on Dairy Waste Disposal, may have other applications. Such unified action will be economical, efficient and productive.

The Association Program

The survey makes available a useful compilation of the types of activities that can be undertaken to advantage by industry organizations. They are:

1. Industry surveys of the pollution situation. How many plants or mills have problems? What is the nature of problems? What litigation? How many have solved problems? How solved?

2. Independent and cooperative research, both fundamental and practical, directed towards the findings from the industry survey. Such research would include studies of (*a*) the composition, quantities and character of wastes, (*b*) the nature of the effects of all wastes on streams, aquatic life and municipal sewage works, (*c*) the sources of wastes, with a view toward prevention or process improvements, (*d*) methods of by-products recovery, and (*e*) methods of treatment and disposal of residual wastes.

3. Industry education in all aspects of the problem. This is accomplished by distribution of (*a*) information on pollution laws, regulatory policies, stream standards, etc., (*b*) bibliographies and abstracts of past and current literature that is pertinent, and (*c*) special reports on research findings. Open discussion of the stream pollution question at industry meetings is also educational.

4. Encouragement of free exchange of information within the industry. This has not been easy to accomplish where competition is keen, but it will benefit the entire industry.

5. Liaison service to bring together all interests concerned with stream pollution toward the ends of mutual understanding, agreement on policy, and unity of action.

6. Advisory consultation services to individual plants and mills. These services should be along the lines of general guidance as to the approach to

the solution; actual design services would be impractical.

The service rendered by the California Fish Canners Association as the medium whereby pollution abatement works were actually built cooperatively to serve several member-companies, is of interest. It would only be possible for an association to undertake such a function when its interests are concentrated into small areas. The idea of cooperative solutions, however, perhaps involving local or regional by-products recovery or waste disposal facilities, may merit further exploration in special cases as a possible association service.

The Association Approach

Handling of pollution abatement functions through the basic committee structure appears to be the most popular and logical industry association approach. Few of these organizations have independent research laboratories or departments to which such matters can be referred directly. Even so, a special committee to channel and direct pollution abatement activities is desirable.

The formula for the industry association approach is aptly phrased by D. V. Stroop, Secretary of the Committee on Refinery Wastes Disposal of the American Petroleum Institute, writing for the July, 1945, issue of the *API Quarterly:*

"Fifteen years of experience with this committee, engaged in the cooperative study of waste-disposal problems having a reasonable degree of similarity, is convincing evidence that an industry working through its national trade association may carry on a successful program of waste disposal, IF:

"1. A substantial part of the industry will support a policy of 'clean it up before it gets away!'

"2. A reasonable number of industry representatives will be willing to work together, if necessary outside of office hours, to the benefit of themselves, their companies, and their industry.

"3. At least one member of the working group will have the initiative, energy, determination, and persistence to see that the work is done—even if he has to do the lion's share of it himself."

Conclusions

There is a satisfying trend toward recognition of the stream pollution problem in industry service organizations. Many industries are unrealistic, however, in their failure to put their own organizations to this proper use.

Most of the industry associations now active are developing programs that were initiated only in recent years, and have not reached their peaks of productiveness. A few are conducting programs that are inadequate and required stimulation and expansion. While some of these programs may have been conceived as "delaying actions" to mollify pollution control authorities, it is believed that the great majority are founded sincerely, on the premise that the days of indiscriminate befouling of natural waters are past.

The recent passage of the Federal Water Pollution Control Act will undoubtedly give impetus to industry action.

Finally, it must not be forgotten that industry association activity is but a means toward the main goal—clean streams. This point is stated emphatically by George E. Dyke, chairman of the Board of Governors of the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industry) in his introduction to the Council's 1947 annual report:

"While the Council will, and properly should, assist member mills technically in the installation of treatment facilities, the burden of seeing that such facilities are installed where pollution problems exist, must rest on individual mills. Obviously, there is little point in the Council's carrying on its program and spending cooperative industry funds in the development of treat-

ment techniques and methods unless the main objective of improving stream conditions is to be reached."

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4. Florida Citrus Commission, L. G. MacDowell, Research Director, Lakeland, Fla.
5. California Fish Canners Association, Inc., R. H. Beaton, Gen. Mgr., Ferry Bldg., Terminal Island, Calif.
6. Manufacturing Chemists Association of the United States, W. N. Watson, Secretary, 246 Woodward Bldg., Washington 5, D. C.; R. W. Hess, Chairman, Stream Pollution Abatement Committee, c/o National Analine Division, Allied Chemical and Dye Corp., 40 Rector St., New York 6, N. Y.
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8. American Electroplating Society, A. K. Graham, Secretary, P. O. Box 168, Jenkintown, Pa.; C. Fred Gurnham, Chairman, AES Research Project No. 10, Hamden, Conn.
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17. American Leather Chemists Association, Fred O'Flaherty, Secretary, Campus Station, Cincinnati 21, Ohio.
18. Textile Foundation, Inc., E. T. Pickard, Secretary, Kent, Conn.
19. Institute of Textile Technology, Ward Delaney, President, Charlottesville, Va.
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NUCLEAR FISSION OPERATIONS AND THE SANITARY ENGINEER*

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It is only natural that members of this Federation should have a keen interest and perhaps some concern over the waste products from such a new industry as that represented by the production of and research in nuclear fission products. The purpose of this paper is to discuss from the point of view of the sanitary engineer the problem of waste disposal in nuclear fission operations; to tell what is being done to resolve them; and to point out some of the opportunities and obligations which lie ahead in helping to establish the new industry on a sound basis in our modern, complex national and community life.

Nature of Nuclear Fission Operations

Perhaps a logical first step toward this objective would be briefly to describe nuclear fission operations as currently practiced since most people, even those in the technical professions, are not familiar with them, and relatively few have been able to visit the plants. In spite of its unique characteristics, however, the operations of this new industry follow a general pattern of other industries in many of its facilities and operating methods. As a consequence there is a definite parallelism in the problems it presents in waste disposal and environmental sanitation. Accordingly, in attacking and resolving these problems well-established principles can be applied subject, of course, to the fundamental differences in the properties of radioactive materials and the special procedures and precautions which must be followed in processing them.

Production

Nuclear fission operations start as do other industrial operations with raw materials which must be refined. The principal one is uranium ore which much be crushed, sieved, and conditioned by a variety of other processes before it is ready for exposure to neutron bombardment in a pile or reactor to produce new substances and energy resulting from nuclear fission. In this preliminary processing, the usual problems exist in protecting workers from dust and fumes encountered in metallurgical and chemical industries. However, in this new industry exposure is more serious than in most others because the natural ore is radioactive, although at relatively low levels.

The highly radioactive materials are produced after neutron bombardment of the prepared uranium in a "pile" or reactor. Here, as a result of nuclear fission, new products are created which are hazardous to handle because they emit particles of high energy which are damaging to living tissues. The heat resulting from nuclear fission is tremendous and must of necessity be controlled or considerable disintegration and possible destruction of the reactor structure itself would take place. In a reactor, this heat is dissipated by

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cooling, using air or water. These coolants, which are used in very large quantities, become radioactive. When they are disposed of they carry with them some radioactive waste products which are potentially hazardous and must therefore be subjected to treatment.

After removal of the highly radioactive materials from a large production reactor, they must then be treated by various chemical and mechanical separation processes common to many industries to permit the particular element which is to be produced—usually plutonium—to be obtained. A property of all radioactive substances is progressive decay through emission of energy. They may emit radioactive particles such as alphas, betas, and gamma radiations. The so-called half-life of a radioactive substance is the length of time required for one-half of its radioactive energy to decay. The half-life of radioactive elements may vary from a few seconds to millions of years. Therefore, by a process of holding, the hazard of handling or exposure to certain short half-life radioactive substances can be reduced. This is an important and significant factor.

As in other industrial chemical processes, there are wastes to be taken care of; and they too are highly radioactive. Those wastes which contain material of sufficient value for recovery are stored while those which, at the moment, have slight economic value must be disposed of. Since all are radioactive and some highly toxic, the techniques of disposal must be carefully developed and constantly supervised.

Research

As contrasted with production plants in the atomic energy industry, there are many research laboratories. Some are small-scale units of production operated for development purposes. Others are for basic research and may handle only radioactive materials or isotopes produced at other plants and transported to these research centers. Again, since these materials are highly radioactive, great care must be taken in their handling and transportation, use and disposal.

Radioisotopes

The Atomic Energy Commission produces and sells radioactive isotopes of various kinds for use and research in medicine, biology, agriculture and industry. In its Fourth Semi-annual Report to the Congress, the Commission lists 3,136 shipments of radioactive isotopes since July 1, 1946, distributed semi-annually as follows:

Distribution of Radioactive Isotopes

	Number of Shipments
July 1 to December 31, 1946.....	246
January 1 to June 30, 1947.....	699
July 1 to December 31, 1947.....	953
January 1 to June 30, 1948.....	1,238
Total to June 30, 1948.....	3,136

From Oak Ridge isotopes have been sent to users in 33 states, the District of Columbia, and Hawaii. Recipients were 236 institutions. By the end of June, 1948, 19 foreign nations had qualified to receive radioisotopes and to 15 of them a total of 159 shipments had been made.

Two isotopes—Phosphorus^{32} and Iodine^{131}—represent 2,024 or about 64.5 per cent of these shipments. Carbon^{14} and Sodium^{24} represent 367 shipments as an additional 10.5 per cent. Thus these four radioactive isotopes account for 75 per cent of the shipments made to date.

Classified by broad fields of professional application these isotope shipments were used as follows:

Use in	Number of Shipments of Radioactive Isotopes July 1, 1946, to June 30, 1948
Medical Therapy	1,291
Animal Physiology	992
Chemistry	262
Physics	257
Plant Physiology	156
Industrial Research	90
Bacteriology	64
Metallurgy	20
Other	4
Total	3,136

The half-lives of some of the more common isotopes currently used for research in medical, public health, industrial and biological laboratories are listed below:

Element	Symbol	Mass No. of Isotope	Half-Life
Carbon	C	14	5,100 yrs.
Zinc	Zn	65	250 days
Calcium	Ca	45	180 days
Sulphur	S	35	87.1 days
Iron	Fe	59	44 days
Phosphorus	P	32	14.3 days
Iodine	I	131	8.0 days
Copper	Cu	64	12.8 hrs.
Potassium	K	42	12.4 hrs.

Control Measures

The usual safety and public health control measures carried out by well managed industries and research institutions are not adequate for complete protection of persons and property in the production and use of nuclear fission materials. This is because of the new hazards introduced by radioactivity. It is a reason why those who have been accustomed to considering industrial and environmental problems in terms of chemical, bacterial, biological and general physical properties must broaden the scope of their appraisal to include radioactivity. This calls for a better understanding of the principles of nuclear physics and familiarity with its technical terms, units and standards, also an ability to interpret them and to blend their values with others in general use.

At plants operated under the Commission's control, measures for protection of working personnel against overexposure to radioactivity usually are carried out by skilled technicians called health physicists. They monitor working areas and see to it that any contamination which occurs is removed and properly disposed of. While their earlier attentions were directed principally to protection against radioactive contamination in-plant and on-site, more recently these specialists have given much consideration to the off-site problems involved when waste from nuclear fission operations for one reason or another are released to the atmosphere, into the ground, or on surface areas.

Sanitary Engineering Responsibilities

It is this environmental phase of the problem which is of special interest to the sanitary engineer. Therefore, it is the one which is emphasized in this paper. It is an area where the opportunity and challenge to sanitary engineers is the strongest and where by reason of his education and training, the sanitary engineer can be of special service.

The sanitary engineer and the health physicist are indeed key men in the progress of this new industry. It has become almost axiomatic that an industry, like a community, can have a healthy program only so long as it can adequately dispose of its own waste products. Nuclear fission operations introduce a new era in industrial development; therefore, every sanitary engineer should acquaint himself with the problems which this new industry will present, especially in disposal of its wastes.

The need of educating and training

sanitary engineers and other specialists in nuclear physics and its applications in the expanding field of atomic energy is recognized by the Commission. A small group of sanitary engineers and chemists in Federal agencies, other than the Commission, are being given training at Oak Ridge and Los Alamos; and it is planned to expand this activity to water and sewage plant operators and public health officials. The need of extensive education and training of sanitary engineers in all categories of the profession—in private as well as public service—in the elements and problems of this new industry is obvious. Programs designed to meet this need are under serious considerations.

Problems of Water Supply

Recognizing that the disposal of radioactive or toxic wastes from its plants or research operations in increasing quantities could create serious problems, the Atomic Energy Commission and its various area contractors have given and are continuing to give much consideration to reducing such contamination to an absolute minimum. But a water-cooled reactor requires a large volume of water for heat-exchange purpose, and this water must be disposed of. The type and degree of radioactivity in such water can be determined and controlled. Knowing the radioactive characteristics of the water leaving the reactor, the period of time it will continue to emit nuclear energy can be determined. Furthermore, through knowledge of the amount of this energy in particles or radiations which the human system can tolerate with safety, it is possible to determine the extent of hazard involved in the disposal of such wastes.

As all radioactive substances undergo decay until they cease to emit energy, knowledge of the length of time required for this decay provides one method of appraising the extent of the problem. Consequently, retention is one method of treatment relied upon for cooling water which must be returned to streams. Unfortunately, some radioactive substances have long half-lives. In such cases, these substances must be removed from water used for cooling reactors unless their quantities are in such small amounts that with dilution the hazard of their existence is negligible.

The technical control on treatment of water used for cooling nuclear reactors must be of the highest order. At atomic energy plants, as well as those of other industry, there is always the remote possibility that an accident or a spill will occur with the result that waste products in abnormal amounts might be released. Great care is taken to avoid such accidents, and provision is made for special treatment and duplicate equipment should they occur. Nevertheless, it should be the concern of every sanitary engineer responsible for water supplies in an area where nuclear fission products are produced or used to appraise and evaluate risks to such supplies under all circumstances. He should work out with operators of such plants a system of routine checks and emergency warnings so that at all times protection against radioactive contamination will be afforded. The Commission cooperates fully with the U. S. Public Health Service in its research program with the states and industry to resolve any problem of stream pollution which may result from its operations.

The discharge of radioactive waste products into or onto the ground also has potentialities of contaminating water supplies; and, here again, long known principles of disposal of wastes from industrial plants apply. Radioactive waste products with long half-lives could create serious hazards and their discharge deserves careful study and effective control. Where such wastes are disposed of to the soil, it is

of basic importance that information be obtained as to the rate of flow of the ground water and of the dilution possibilities, so that at all times the extent and degree of contamination may be known. Fortunately, some radioactive substances are known to attach themselves firmly to soil and do not travel far from the point of disposal in soil. As a result, they undergo decay in a localized area and spend their radioactive energy before they could be transported to more distant sources of water supply. But this favorable relationship should not be accepted as adequate protection under all circumstances. Common prudence dictates that the facts in each case should be obtained where sources of water supply might be involved.

There is evidence that such processes of water purification as coagulation and sedimentation and sand filtration are quite effective in removing some radioactive substances from water. The problems of disposal of the radioactive sludge and controlling the build-up of radioactivity in filter media are deserving of special consideration. These are being studied by the Atomic Energy Commission, and facilities for extending research of this kind are being installed at Oak Ridge and Los Alamos.

Radioactive particles carried into the atmosphere by gaseous effluents from nuclear fission operations could contaminate the air and, on settling with or without rainfall, contaminate the soil and vegetation on which they deposit. Thus watersheds and open reservoirs could become contaminated if the half-life of the radioactive product is long. Here again, the elements of time and dilution, as well as fixation, are factors of safety. But an alert and responsible sanitary engineer should not accept these favorable influences as a substitute for determining the facts.

Still another aspect of radioactivity in water, interesting and significant to sanitary engineers and biologists, is evidence that such energy does not unfavorably affect many plankton growths and is accumulated within these organisms. Algae and other forms are known to grow prolifically in water which is quite radioactive. The potentialities and significance of this finding are especially interesting and important to all interested in the biology of streams and their subsequent use as sources of industrial and public water supplies.

Community Water Supplies

At Oak Ridge, Hanford, and Los Alamos the Commission, through its contractors, operates communities housing and serving about 60,000 persons, including employees and their families and, during periods of expansion, construction camps for tens of thousands of temporary employees. The problem of supplying water to these areas has been much more involved than that of providing water for normal communities of the same size. This has been due partly to the fact that new communities had to be built hurriedly in remote areas and under difficult conditions.

At the Richland, Wash., village, housing employees of the Hanford Works, the per capita consumption of water on hot days is about 1,100 g.p.d. over two-thirds of which is for sprinkling lawns and parkways. Currently, more than half of the water supplied Los Alamos Village must be pumped an elevation of nearly 2,000 feet.

Private water works consulting engineers were employed to design these facilities and have successfully resolved the problems involved.

Problem of Waste Disposal

Wastes from nuclear fission plants, as from most industries, are liquid, dry, and gaseous. It is the policy of the Commission to develop ways and means of treating wastes resulting

from production and research activities at plants under its jurisdiction so that there will be no hazards to its employees or to others. Toward this end special working groups of outside consultants are collaborating with staff employees in various areas of operation and at research institutions.

Liquid Wastes

Because of the scarcity of the raw material, such as uranium ore, and the value and importance of fission products resulting from the separations processing subsequent to bombardment in the reactors, great care is taken not to lose these products. This calls for on-site storage of large quantities of valuable and highly radioactive materials, especially at production plants. Waste products with little value but having radioactive or toxic properties must be disposed of. This poses a problem both of economics and of safety. Cribbing and lagooning, which are common practice in many industries, have been carried out with a fair measure of success, but it is recognized that such practices have potential hazards and limitations.

With the objectives of maximum product recovery and minimum of radioactive waste to be disposed of, the Commission is seeking to develop processes which will in effect result in a closed system. One of the unique problems in the nuclear fission industry is that equipment and facilities which come in contact with highly radioactive contamination also become contaminated and, therefore, must be decontaminated or be disposed of. For this reason, use of many of the methods and of much of the equipment common to other industries for treatment of industrial waste must be ruled out or modified because of the end problem of ultimate disposal. This need of developing equipment small in size and methods which will minimize human exposure is a complication which must be faced at all times in seeking practical solutions to problems of disposal of wastes in the field of nuclear fission.

The ability of certain natural soils and artificial media and resins to adsorb radioactive liquid wastes is a subject of much interest and research. The possibility of concentration of radioactivity by biological methods and, conversely, the effect of various amounts of radioactivity on biological processes common to sewage treatment are being studied.

There has been some concern on the part of operators of sewage treatment works that the disposal of waste resulting from the use of radioactive isotopes at hospitals and research institutions might have an adverse effect on the sensitive biological processes at these works. Their concern is wholly understandable and, currently, research programs are being initiated to obtain basic facts. The rapid increase in the use of radioactive isotopes in institutions and industry poses many other problems which call for answers such as the degree, if any, to which plumbing fixtures in buildings can become radioactive and to what extent facilities in sewer systems such as receiving basins, sump and booster pumps will require monitoring before being entered or handled by workmen.

Radioactivity is indeed a type of contamination to which the sanitary engineer of the future will need to give serious consideration, and be able to measure and to interpret. Its potential as a contaminant in cases where interconnections between piping systems in buildings or institutions exist is as insidious as it is hazardous.

Dry Wastes

In the various processing stages, especially in metallurgy, dusts and chips of radioactive and, in some cases, toxic materials result. That which can be is reclaimed. As a rule the remainder, if of a low level of radioactiv-

ity, is buried. If of high level, it is stored in a container—well shielded against radioactivity—for subsequent burial when it is safe to do so in the ground, usually in the same container. In addition, instruments, containers, glassware, and facilities used in handling radioactive materials become contaminated to a degree where they must be condemned for further use. Again, depending on the degree of radioactivity, these items are disposed of by burial either in shielded containers or direct. Incineration of radioactive materials is not advisable unless adequate facilities are available to remove all activity from the resulting gases, which in itself is not a simple task. The entire problem of disposal of so-called dry wastes resulting from nuclear fission operations is receiving much attention.

Gaseous Wastes

Certain constituents of the air which are passed through an air-cooled reactor become radioactive. The concentration is low and the half-life short. Therefore, if operation is discontinued when atmospheric conditions are most unfavorable, it is possible by the use of special air treatment equipment to meet with a higher factor of safety the permissible limit established for atmospheric contamination.

As in most chemical processing—dry or in solution—very small particles in dust or mists are carried away through the ventilating systems. Those which are radioactive could create a hazard, especially if discharged to the atmosphere in such a way as subsequently to expose humans or vegetation in amounts which would be injurious. Similarly exhaust gases from hoods in experimental and research laboratories could, on a lesser scale, create local hazards.

The Commission is keenly aware of this stack gas problem and has authorized the installation of most elaborate equipment for filtering and otherwise removing particles and gases from stack and hood discharges. In this field, as in that of liquid waste disposal under the direction of a special committee of consultants, work is being pressed looking forward ultimately to the complete removal of all gaseous wastes from Commission plants, and the development of new or adaptation of existing gas treating facilities for highly efficient operation under conditions singularly peculiar to this new industry.

Techniques and Tolerance Limits

In any consideration of contamination, scientists are accustomed to make use of certain standards or permissible levels. Sanitary engineers already need some guides as to relative degrees of radioactive contamination, techniques for their measurements, and safe limits for public safety and health. The radiologist and the health physicist have done much to develop such techniques, standards and equipment, and deserve much credit for their work along these lines. By means of instruments such as electroscopes, Geiger counters and ionization chambers, they evaluate the radioactive energy from nuclear particles, such as alpha and beta particles and gamma radiations. They have made much progress in developing instruments of increasing sensitivity and accuracy. More work along these lines has to be done before the sanitary engineering profession has the tools it needs to work with. The sanitary engineer and the so-called health physicist have a lot in common and each has much to give and receive of his knowledge and experience in the development of this branch of science.

Ultimately, permissible levels for radioactivity developed and being used currently at plants under the Atomic Energy Commission will have to be subjected to intensive review by outside experts of wide experience in medical and public health and safety research. They naturally will want all standards

recommended to be supported by clinical, epidemiological, and bio-metric evidence before they are generally accepted. The history of the evolution of other technological standards, which have stood the test of time, forewarns us of this eventuality.

The current values were arrived at largely by mathematical calculations as to equivalent energies involved in different substances and relating these to experience in exposure of humans and animals to radium. The International Congress of Radiobiology in 1934 had set a limit at 200 milli-roentgens (mr) per day, while the American Advisory Committee on X-ray and Radium in 1936 had set the figure as 100 mr per day for X and gamma radiation. Limits currently used stem from a tolerance level for total body exposure of 0.1 roentgen equivalent man (rem) in any 24-hour period. In the case of alpha emitters such as plutonium, the objective in establishing limits is to prevent disposition of a total of more than 1.0 microgram in the body during a person's life.

Morgan gives the permissible limits for 24-hour exposure of employees as established in the Clinton Laboratories and used by a number of other laboratories as follows:

100 (mr) for X and gamma radiation.
100 (mrep) for beta radiation.
10 (mrep) for alpha radiation.
20 (mrep) for fast neutrons.
50 (mrep) for thermal neutrons.

Morgan makes the significant point that the factors of safety are low and that these figures should be considered as "maximum allowable" rather than "tolerance" amounts of radiation. In the same paper from which these data are taken he presents extended curves and tables summarizing values for tolerances over one year both in air and water. The values are tentative and much too detailed to be reproduced here in full, but a few figures are listed below as examples:

Element	Assumed Effective Half-Life	One-Year Tolerance Concentration			
		In Air		In Water	
		Micro-curies (per cc.)	Micrograms (per cc.)	Micro-curies (per cc.)	Micrograms (per cc.)
RA^{226} pdts	2 wks.	2×10^{-10}	2×10^{-10}	—	—
RA^{226} pdts	10 yrs.	—	—	4.4×10^{-6}	4.4×10^{-6}
C^{14} (graphite)	2 mos.	1.2×10^{-7}	2.6×10^{-8}	—	—
Na^{24}	14.8 hrs.	6.3×10^{-7}	7.1×10^{-14}	4.9×10^{-4}	5.5×10^{-11}
Ca^{45}	150 days	2.1×10^{-7}	1.3×10^{-11}	3.6×10^{-3}	2.2×10^{-7}
S^{35}	25 days	3.1×10^{-6}	7.3×10^{-11}	0.041	9.4×10^{-7}

Current Activities

A great deal of excellent work has been carried out and is in progress or planned for resolving the problem of protecting man and his environment against radioactivity. Of special interest to sanitary engineers are the following:

Meteorology

At the Hanford Works careful experiments have been carried out to determine the most favorable atmospheric conditions under which to carry out operations. Equipment for similar studies has been installed at the Brookhaven National Laboratory where perhaps the most extensive meteorological program of all areas will be carried out. The U. S. Weather Bureau will assist in studies of atmospheric problems at most of the larger areas of operation.

Safety Manual

A manual of Standard Safety Requirements has been prepared containing information to be used by plant operators in protecting personnel and by designers in preparing plans for new and for revision of existing plants and facilities.

Ground Water Protection

The U. S. Geological Survey has been requested to cooperate in studies and evaluation of surface and subsurface contamination of water supplies where radioactive and toxic wastes may be discharged into or onto the ground. Such problems are currently being given special consideration at the Hanford Works in Washington, Oak Ridge in Tennessee, and at the Brookhaven National Laboratory on Long Island.

Waste Disposal Research

Contracts have been let with several nationally known chemical engineering and development companies for research to improve chemical processing and recovery of valuable products from stored wastes and for reducing the volume and radioactivity of final plant wastes to the smallest amount practical. Cooperative programs with the Public Health Service and the Tennessee Valley Authority have been developed at Oak Ridge, with the Public Health Service at Los Alamos, and with New York University for study of the effect of radioactivity on biological processes, especially those common in sewage treatment and stream pollution. Included in one or more of these programs will be studies of the effect of radioactive isotopes on various materials used in plumbing and sewers and related facilities. The cumulative effect of radioactivity in algae and various plankton forms, and the effectiveness of standard water purification methods in removing radioactive contamination from water will also be studied.

A program for studying the Columbia River in the vicinity of the Hanford Works is being developed with the Public Health Service. The construction of McNary Dam—35 miles downstream from these works—is expected to have a considerable effect on the biology of the river upstream from the dam, and it is desired to determine the effect and any relation this may have to operations at the Hanford Works.

Use of Sanitary Engineers

At most of the larger AEC areas, sanitary engineers are employed to assist in the solution of problems in water supply protection, waste disposal and general environmental sanitation, including related problems in the villages where workers are housed. The Atomic Energy Commission recognizes the need of complete control over the various environmental factors which concern and affect this new and unique industry. It is most anxious that in its current operations and in the expansion which is sure to come, full advantage be taken of the experience of other new industries in order that their earlier difficulties may be avoided. Many of the areas of vulnerability in the atomic energy field which affect environmental sanitation are those in which the sanitary engineer is especially trained to help. As the industry grows, there will be an increasing need of assistance from sanitary engineers, both at atomic energy plants and in areas surrounding them.

When one considers the potentialities of wartime hazards involved in the field of atomic energy, whether in production for military purposes or the possibilities of enemy action, the importance to the national defense of having a large number of sanitary engineers trained in ways and means of coping with hazards of nuclear fission products is evident to a sharp degree.

Conclusion

It is re-emphasized that (1) the continued expansion of the nuclear fission industry presents many problems and, therefore, an opportunity and a challenge for the trained sanitary engineer; (2) the Atomic Energy Commission is striving actively for a permanent solution of its waste disposal problems; (3) its objective is that this new industry may expand to meet its potentialities without creating objectionable or hazardous conditions at and in the vicinity of its plants as many new industries have done; (4) sanitary engineers should be trained in fundamentals of nuclear physics so that they may have a better understanding of this new industry and its environmental problems; and (5) the need of training sanitary engineers is especially acute considering their responsibilities in a national defense program.

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NUCLEAR FISSION OPERATIONS—A DISCUSSION

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Mr. Gorman has stated that nuclear fission operations, whether in production or research, have created problems of industrial hygiene and waste disposal akin to those of metallurgical and chemical industries.

This parallelism may be carried one step farther to indicate that just as in the metallurgical and chemical industry, the problems are diversified and require special studies depending on the unit processes in use. Thus in the pile production of radioactive isotopes, W. E. Cohn (1) lists a choice of 18 elemental targets, 15 oxide targets, 5 carbonate targets, 4 nitrate targets, and 4 potassium and beryllium salt targets suitable for bombardment to make specific radioactive isotopes. To illustrate the production of one of hundreds of radioactive istopes Cohn (1) states that "one of the few n,p reactions which proceeds at a satisfactory rate in the pile is that on N^{14} to yield C^{14}. The process in use for the recovery of C^{14} from irradiated $Ca(NO_3)_2$ takes advantage of the fact that practically all the C^{14} created during the nuclear transformation period apparently exists in the crystal lattice as CO_2 and can be obtained as such by simple solution of the parent salt in water followed by

acidification and aeration. Two coexisting gases are evolved, O_2 (from the radiation decomposition of No_3^- to NO_2^-) and A^{36} (from the neutron, alpha reaction on a Ca^{40}). . . . The $C^{14}O_2$ is trapped in $Ba(OH)_2$ and is shipped as solid $BaCO_3$." It appears therefore that there are environmental sanitation and waste disposal problems specific to the production, separation, and purification of a particular radioactive isotope as well as problems arising from fission products produced and coolants used in the pile reactor.

Mr. Gorman has indicated the problems incidental to the enrichment of uranium and other ores, the production of plutonium from a chain reacting pile, and the use of radioactive isotopes in medical and industrial research. One might well speculate that, although similar to pile production, there are even more diversified problems in the Cyclotron and other methods of radioactive isotope production (2) and in the use of radioactive isotopes for the production of power or for experimental purposes.

The nuclear physicists, chemists, engineers, and management active in the growth and development of this new industry have taken due cognizance of the radiation hazards and have developed instruments of measurement and standards of safety for personnel protection, air and water tolerances, etc. To achieve these standards temporary measures and theoretical deductions have often been improvised pending a more permanent solution.

Dr. Karl Z. Morgan, Director of the Division of Health Physics at the Oak Ridge National Laboratory, has led in the promotion of studies to evaluate more accurately the hazards and obtain permanent solutions. Over a year ago a group of nationally known sanitary engineers were consulted for a program of study. Preliminary plans for seeking the service of USPHS and TVA sanitary engineers were made. Subsequently the Monsanto Chemical Company contract was given to Carbide and Carbon Chemicals Corporation. During the last nine months Dr. A. H. Holland, Jr., Director, Office of Research and Medicine of the Oak Ridge Directed Operations of AEC, promulgated a cooperative arrangement whereby USPHS sanitary engineers, TVA Health and Safety Division men and allied specialists, U. S. Weather Bureau meteorologists, University of Tennessee geologists, and others, would undertake various phases of air, water, soil, plant and animal studies on the behavior of radioactive wastes.

To handle principally the problem of liquid disposal and the behavior of radioactivity in process and other waters, a new section—the Waste Disposal Section—was formed in the Health Physics Division of Oak Ridge National Laboratory. Pending security clearance a chemist and chemical engineer will be added to the staff within a few weeks.

Augmenting this group, the Health Physics Division will supply regular counting-room service, technical health physics and chemistry assistance and training, and special instrument development and maintenance.

Tentative cooperative arrangements between the Division of Health and Safety, TVA, and the Oak Ridge Directed Operations of the AEC have been made so that various branches of the TVA are participating in the program by supplying special technical aid, equipment and information.

Reconnaisance surveys have been made, structures for experimental water and sewage pilot plants have been proposed, literature searches are progressing, and laboratory bottle studies will be undertaken within the next few weeks. The team is a well coordinated group under an inspiring leadership and a determination to achieve worthwhile results.

Similar teams have been or are being

organized at other sites. Whether their objectives are the same or not, the diversity of the nature of the problems at different sites, and the urgent need of solutions in light of the general world condition in this atomic age require many more men in the sanitary engineering and allied sciences to be interested in and acquainted with this new field.

References

1. Cohn, W. E., "Pile Production of Radioactive Isotopes." Supplement, *U. S. Naval Medical Bulletin*, March–April, 1948, page 42.
2. Irvine, J. W., Jr., "Production of Radioactive Isotopes by the Cyclotron and Other Methods." Supplement, *U. S. Naval Medical Bulletin*, March–April, 1948, page 52.

UNIVERSITY OF MICHIGAN OFFERS STREAM SANITATION COURSE

The School of Public Health of the University of Michigan is offering an In-service Training Course in Sewage and Industrial Waste Disposal Problems, which will be held March 14–15, 1949 at Ann Arbor, Mich.

Planned in cooperation with the Educational Committee of the Michigan Sewage Works Association, the course will be of the high technical level, post graduate seminar type, providing a comprehensive technical review, analysis, and interpretation of the basic scientific considerations involved in problems of waste disposal. Subjects to be discussed include: collection and evaluation of pertinent data relating to stream sanitation; use of biological indicators in determining stream pollution; bacteriology of stream sanitation; and the fundamental and practical aspects of the chlorination of wastes in relation to stream sanitation.

A special faculty of outstanding stream sanitation authorities has been arranged for the course, consisting of L. L. Hedgepeth, H. W. Streeter, C. J. Velz, James B. Lackey, W. L. Mallmann, Edward W. Moore, and L. F. Warrick.

The course is designed especially for scientific workers of both industry and the official agencies, who are engaged in sewage and industrial waste disposal. Others interested in the subjects to be discussed, however, are welcome to attend.

Applications for enrollment in the course should be submitted in writing to the School of Public Health, University of Michigan, Ann Arbor, Mich. The enrollment fee is $5.00; the closing date for enrollment, March 7, 1949.

A limited number of rooms is available at the University of Michigan Union. In making reservations, it is necessary to state that accommodation is requested in connection with attendance of the wastes disposal course.

A METHOD FOR TREATMENT OF WOOL SCOURING WASTES *

By Joseph A. McCarthy

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From the standpoint of stream pollution in Massachusetts, wool scourings present one of the most important industrial waste problems. For the last year for which records are available, the production of wool in the entire United States was 307 million pounds, while the amount scoured in Massachusetts was 370 million pounds. The volume and concentration of wastes produced vary within wide limits from one plant to another, depending on the type of wool scoured, the variations in process, the amount and quality of water available, and the degree of recirculation or re-use and of partial treatment, generally involving grease recovery; and finally, it has been found that the volume which can be handled by present lagoons, settling tanks and other means of disposal sometimes influences the volume of water used in scouring.

The four mills which have been investigated in the past few years (Tables I and II) showed a variation of waste produced per 100 lb. of wool of from 100 to 155 gal., with an average of 126 gal.

These wastes are probably somewhat more concentrated than the material from the average wool scouring mill. The wastes from Mill A and Mill C were collected after they had been centrifuged for grease recovery; the amount of grease remaining is partly a measure of the efficiency of this process, but is also governed somewhat by the type of wool being scoured.

All of the mills pass the wastes through some sort of a "sand-catcher" in which most of the sand and other heavy inert material, but very little organic matter, is removed. Since all samples were collected after this grit removal and after centrifuging, if any, they fairly represent the wastes as discharged to treatment processes or to the stream. Tables I and II show the average analyses of these wastes and the pounds of stream polluting materials per 100 lb. of wool scoured.

Much of the grease is in suspension or in emulsion. Where centrifuges are employed, most of the grease removed is that in relatively free suspension. The remainder, which may be from 50 to 80 per cent of the total, is more intimately mixed. Most of the B.O.D. is in suspension, but because of the emulsified nature of the waste, comparatively little of either B.O.D. or grease is removed by normal sedimentation. The pH is always high, generally with considerable amounts of caustic alkalinity. The wastes ferment quite rapidly, and hydrogen sulfide is often produced by the fermentation. All of these factors contribute to the importance of the wastes in problems of stream pollution, frequently aggravated by the fact that many of the mills are on comparatively small streams.

Methods of Disposal

The wastes are generally much too concentrated for normal biological treatment without considerable dilution; studies at the Lawrence Experiment Station and elsewhere have shown

* Presented at the 1948 Spring Meeting, New England Sewage Works Association, Marlboro, Mass., May 12, 1948.

TABLE I.—Analyses of Wool Scouring Wastes from Four Mills

Mill	Dissolved Solids (p.p.m.)			Suspended Solids (p.p.m.)			pH	Ammonia (p.p.m.)		Alkalinity (p.p.m.)		Fats (p.p.m.)	Oxygen Consumed (p.p.m.)	5-day B.O.D. (p.p.m.)
	Total	Vol.	Fixed	Total	Vol.	Fixed		Free	Alb.	M.O.	Phen.			
A	37,800	26,700	11,100	12,300	8,400	3,900	8.8	120	270	5,300	300	17,900	2,780	12,700
B	33,100	20,500	12,600	5,640	3,820	1,820	9.5	500	250	8,100	1,200	11,500	2,080	10,700
C	16,000	9,200	6,800	5,200	2,340	2,860	8.9	—	—	—	—	3,740	1,500	3,000
D	24,000	12,000	12,000	6,100	4,100	2,000	9.1	52	230	6,800	2,500	6,800	3,500	10,800
Ave.	27,700	17,100	10,600	7,300	4,700	2,600	9.1	220	250	6,700	1,300	10,000	2,470	9,300

that the addition of 1 to 2 per cent of wool scourings to domestic sewage did not interfere with the normal operation of slow sand filters, and that trickling filters would not be affected seriously if the percentage of wool waste was even somewhat higher. In some English textile towns, even though the volume of textile wastes was equal to or even greater than that of the domestic sewage, trickling filters have handled satisfactorily the settled mixture, generally after chemicals have been used to supplement normal sedimentation.

Many methods of chemical coagulation have been proposed for treatment of wool scourings. The use of sulfuric acid in various "cracking" processes has been tried in many plants throughout New England, and is still in use at some mills. This process is used mainly, however, for the purpose of grease recovery, and generally only secondarily with a view to stream improvement. This method does remove a great part of the grease, and the plate presses generally used in the process effect the removal of much of the inorganic suspended solids, which are usually dumped or lagooned. But practically none of the dissolved organic material is removed, and a considerable part of the non-fatty suspended organic matter remains in the liquors discharged from the presses. These liquors are generally quite acid, with a pH of 3 to 4, and contain some emulsified grease with a great part of the original B.O.D.

Many other chemicals have been used for coagulation of wool wastes. Forty years ago this Station reported on the value of lime, iron salts, calcium chloride, and "chloride of lime," or calcium hypochlorite, in dosages up to 30,000 lb. per m.g. Recently there has been new interest in such chemical methods, particularly in a successful method for using $Ca(OCl)_2$ which has been developed and is now in use at one of the Massachusetts mills.

TABLE II.—Stream Pollution Constituents of Wool Scouring Wastes from Four Mills, Expressed in Pounds per 100 lb. of Wool Scoured

Mill	Dissolved Solids			Suspended Solids			Ammonia		Alkalinity		Fats	Oxygen Consumed	5-day B.O.D.
	Total	Vol.	Fixed	Total	Vol.	Fixed	Free	Alb.	M.O.	Phen.			
A	31.5	22.2	9.3	10.3	7.0	3.3	0.10	0.23	4.4	0.25	14.9	2.3	10.6
B	33.1	20.5	12.6	5.6	3.8	1.8	0.50	0.25	8.1	1.2	11.5	2.8	10.7
C	20.8	11.9	8.9	6.7	3.0	3.7	—	—	—	—	4.9	1.9	3.9
D	27.6	13.8	13.8	6.3	4.2	2.1	0.22	0.24	6.4	1.4	9.4	2.6	9.1
Ave.	28.3	17.1	11.2	7.2	4.5	2.7	0.27	0.24	6.4	1.38	9.6	2.6	9.2

Study of such processes at the Experiment Station led to the belief that the coagulation caused by the calcium ion is the most important part of the improvement in the waste from a stream pollution standpoint, although other ions, such as the free chlorine in the hypochlorite process, also had definite beneficial effects. This prompted a review of some of the earlier work at Lawrence, especially on various calcium salts. It was found that either hydrated lime or quicklime failed to give a clear-cut precipitation; a floc could be formed, but the fats could not be separated at all readily, because they tended to remain in widely dispersed emulsion. In some of the experiments, even after 2 to 3 hours the floc remained floating, with no clear zone, although there could be observed small clear areas of liquid in the interstices of floc.

The next source of calcium ion investigated was calcium chloride. Exploratory experiments showed that even with the relatively weak wastes available for study at that time, it was necessary to use the chloride in amounts approaching 1 per cent of the total weight of the waste; and it was also found that the required amount was indicated by the reduction of the pH to somewhat below 8. Once this point was reached, floc formed almost instantaneously, and began to settle quite rapidly, leaving a very clear supernatant. It had been found with other coagulants that any floc formed tended to divide, with about one-half settling to the bottom and the remainder rising to the top, leaving a clear zone in between, generally with watery emulsions below the top layer and above the bottom sludge. With the chloride, however, little or no scum rose to the top, and the line of separation between bottom sludge and liquid was clear-cut. The volume of sludge after 1 to 2 hours of settling was found to be about 15 per cent.

It was realized that a considerable part of the coagulant must have reacted with the carbonates in the waste. In much of the earlier work on various strongly alkaline wastes at the Experiment Station, especially in the study on laundry wastes as reported in *Public Works*, Vol. 73, No. 7 (July, 1942), it had been found that considerable over-all economy in amount and cost of coagulants could be obtained by using acid to reduce the alkalinity. Generally, the greatest economy was obtained if acid equivalent to about $\frac{2}{3}$ of the total alkalinity was applied before any coagulant. It had also been found that carbon dioxide could be used satisfactorily for this reduction in alkalinity, especially with wastes having a pH of 9 or higher. Work on tannery wastes, in particular, had shown that the necessary carbon dioxide could be most cheaply obtained by using flue gas, which contains from 12 to 18 per cent of CO_2, and is generally readily available.

Calcium Chloride—Carbonation Treatment

The next experiments, therefore, were on the combined use of calcium chloride and carbon dioxide. The latter was obtained by burning illuminating gas in a tower, from which the CO_2 and air were drawn through the waste by a suction pump. It was found that equally good results were obtained by adding the chloride before, after or during the carbonation of the waste, but control was found easiest when the two were applied simultaneously. It was also found that it was necessary to add two to three times the volume of carbon dioxide theoretically required to react with the carbonates and hydroxyl ion present. The experiments showed that the use of the carbon dioxide made it possible to effect reductions in the amount of calcium chloride of from 20 to 50 per cent, or to obtain much more satisfactory coagulation with a given amount of chloride.

Table III shows the results of treatment of a weak waste.

Pilot Plant Studies

Further experiments on somewhat more concentrated wastes from the same mill gave similar results, and a pilot plant was set up in which 600 to 800 gal. of waste were treated daily on a fill-and-draw basis. During the operation of this pilot plant, the mill used both detergent and soap scouring, and the treatment process worked equally well on both types of waste. The average amount of calcium chloride required on the normal scouring wastes was found to be 0.86 per cent by weight, and sufficient CO_2 was used to reduce the pH to about 8. The waste was relatively low in alkalinity during these runs, and it was found that neutralization by carbon dioxide was obtained as soon as stirring by the gas effected a thorough mixture of the chloride with the waste.

With this particular waste, plain aeration with air was found to be almost as satisfactory as CO_2 in reducing alkalinity, but a longer time of blowing was necessary. In any case, it was always found that either type of aeration resulted in saving of coagulant, as well as sharper and cleaner separation of sludge, and it was now quite definite that the use of carbon dioxide was necessary for best results. The average reductions obtained from treating the scouring liquors were 98 per cent in suspended solids, 90 per cent in fats, and over 70 per cent in B.O.D.

Meanwhile, laboratory experiments

TABLE III.—Results of Treatment of a Weak Wool Scouring Waste with $CaCl_2$ and CO_2

	pH	Sludge, after 2 hrs. Settling (% by vol.)	Suspended Solids		Fats (p.p.m.)	B.O.D. (p.p.m.)
			Total (p.p.m.)	Volatile (p.p.m.)		
Untreated waste	9.9	—	2350	1800	5300	2720
Supernatant after 1% $Cacl_2$	7.9	14	102	87	700	760
Reduction (%)	—	—	96	95	87	72
Supernatant after carbonation plus 0.5% $CaCl_2$	8.1	22	18	16	410	620
Reduction (%)	—	—	99	99	92	77
Supernatant after carbonation plus 1.0% $CaCl_2$	7.8	27	20	18	470	520
Reduction (%)	—	—	99	99	91	81

had shown that heating the waste to 40° to 45° C. increased the speed of floc formation. However, after 2 to 4 hours of sedimentation the heated waste showed comparatively little reduction in sludge volume as compared to unheated runs, and in 6 to 12 hours there was practically no difference between heated and unheated samples. It was found that the waste at most mills is discharged at 30° to 50° C., and it was indicated that it would be desirable to treat wastes at these higher temperatures if possible.

Experiments were then conducted on wastes from a mill scouring carpet wools, which are generally not high in grease content but do contain large amounts of grit and of finely divided organic matter. The wastes as treated were much more concentrated than any previously tried. As expected, higher amounts of calcium chloride were required, but again, carbon dioxide was found to reduce materially the amount of chloride necessary. Without carbonation, 1.6 per cent of chloride was found to be the optimum dose; when carbon dioxide was also used, the concentration of chloride could be reduced to 1.25 per cent. Table IV shows the average results of several runs.

A large scale test of calcium chloride treatment was then made at this same plant. It was not possible to arrange for any carbonation, and no facilities for feeding chloride were available, so that in making the run the chloride was fed by hand into a 12,000-gal. tank as this was being filled with waste. As a result, a considerable part of the coagulant went to the bottom of the tank without reacting, and the active dose of chemical was somewhat below optimum. Even under these handicaps, analyses showed a reduction of 97 per cent in suspended solids, 82 per cent in fats, and 72 per cent in B.O.D. The sludge volume was about 17 per cent, and scum formation was negligible. The sludge contained 12.7 per cent of solids and 4.1 per cent of fats.

Coagulation and Flotation Treatment

The next experiments were on a very concentrated waste from a mill scouring high-grease wool and using a minimum amount of water, with a centrifuge system which removed about 25 per cent of the fats. Laboratory runs showed that 1.25 per cent of calcium chloride with carbonation, or 1.6 per cent of calcium chloride without carbonation, gave average reductions of 97 per cent in suspended solids, 99 per

TABLE IV.—Results of Treatment of a Strong Wool Scouring Waste with $CaCl_2$ and CO_2

	pH	Sludge, after 2 hr. Settling (% by vol.)	Suspended Solids		Fats (p.p.m.)	B.O.D. (p.p.m.)
			Total (p.p.m.)	Volatile (p.p.m.)		
Untreated waste	9.5	—	5,640	3,820	11,500	10,700
Supernatant after 1.25% $CaCl_2$	7.6	26	320	260	1,130	3,000
Reduction (%)	—	—	94	93	90	72
Supernatant after carbonation plus 1.25% $CaCl_2$	7.3	26	30	21	370	2,100
Reduction (%)	—	—	99	99	97	80
Supernatant after 1.6% $CaCl_2$	7.3	26	45	25	360	2,000
Reduction (%)	—	—	99	99	97	81

cent in grease and 85 per cent in B.O.D.

Following these experiments a pilot flotation apparatus was set up at the mill. This consisted of two vertical cylindrical tanks in series, with upward flow in the first tank and downward flow in the other. Calcium chloride solution was applied to the waste entering the first tank. Flotation was effected by "eductors," an adaptation of the aspirator principle, by which very finely divided bubbles under minimum pressure were released near the bottom of each tank. Carbon dioxide and air were fed into the eductor intakes. The sludge resulting from the reaction was buoyed up by the fine bubbles and was removed over a weir by rotating helical blades. The clear liquor discharged through an outlet submerged below the sludge removal apparatus.

The flotation apparatus was not particularly suited to the work required, but eventually operating difficulties were sufficiently overcome to permit the operation of six runs of 3 to 4 hours each. The effluents from these runs—with an average calcium chloride dosage of about 1.5 per cent and maintenance of a pH of about 7.6 by the use of CO_2—showed an average reduction of 97 per cent in suspended solids, 96 per cent in grease, and 85 per cent in B.O.D. The treated wastes were practically free of suspended matter, but further settling of 1 hour increased these removals so that the final suspended solids were 135 p.p.m. (99 per cent removal), fats 450 p.p.m. (97 per cent removal), and B.O.D. 1,580 p.p.m. (88 per cent removal). The amount of scum was extremely small, and the effluent was generally very clear, deep yellow to reddish in color, with a rather pronounced lanolin odor, and quite stable. Two effluent samples from these runs have remained unchanged in appearance in the laboratory for 7 months, and another sample remained unchanged until a growth of blue-green algae took place. Table V shows the results of these runs.

The flotation apparatus was then moved to another plant, where the fill-and-draw tanks had been operated during the summer. Comparatively clean domestic wools were being scoured and the wastes were much weaker than those in the previous experiments. Persistent operating difficulties were again encountered, but eventually it was possible to make prolonged runs producing continuously a clear effluent.

Careful sampling throughout this run showed reductions up to 98 per cent in suspended solids and 94 per cent in fats, but the B.O.D. removal was only 54 per cent. The average amount of calcium chloride was 1.8 per cent by weight, but due to difficulties in carbon dioxide feed, practically all the gas fed to the eductors was air.

TABLE V.—Results of Coagulation and Flotation of Wool Scouring Wastes (Mill A)

	pH	Suspended Solids		Fats (p.p.m.)	B.O.D. (p.p.m.)
		Total (p.p.m.)	Volatile (p.p.m.)		
Untreated waste	8.4	12,300	8,400	17,900	12,700
After carbonation plus 1.5% $CaCl_2$ and flotation	7.6	135	101	450	1,580
Reduction (%)	—	99	99	97	88

TABLE VI.—Results of Coagulation and Flotation of Wool Scouring Wastes (Mill C)

	pH	Suspended Solids		Fats (p.p.m.)	B.O.D. (p.p.m.)
		Total (p.p.m.)	Volatile (p.p.m.)		
Untreated waste	8.9	5,200	2,300	3,700	3,000
After 1.7% $CaCl_2$ and flotation	7.5	75	60	400	1,130
Reduction (%)	—	99	97	98	62

Meanwhile, laboratory runs indicated that much higher removals of B.O.D. were possible with the proper combination of carbonation and calcium chloride. Table VI shows the results of the most successful of the runs with the flotation apparatus.

Mechanics of Process

It was noticed in all these experiments that with any given waste there seemed to be an irreducible minimum B.O.D. beyond which it was difficult to go. Analyses showed that this was generally equal to the dissolved B.O.D., indicating that the process was removing practically all the suspended B.O.D. together with practically all the suspended solids, and the fats which were largely in suspension. It was found possible, however, by most careful adjustment of pH and of coagulant, to reduce still further the B.O.D., indicating that true precipitation could be effected to a degree that perhaps 25 to 30 per cent of the dissolved B.O.D. could also be removed together with practically all that in suspension. It is rather doubtful if such removal will be economically justified.

Study of the mechanics of the coagulation effected by the process indicates that floc formation begins with the precipitation of calcium carbonates and of what may be loosely grouped as calcium soaps, around a nucleus of calcium chloride. Further, it appears that the floc grows by enmeshing organic matter, and probably fatty emulsions, in the further concentric layers of calcium soaps and carbonates. The presence of a calcium chloride nucleus has been suggested by the fact that analysis, even after the most careful addition of coagulant, has always shown higher chlorides in the sludge than in the clarified liquor. This would be expected, of course, when wastage of chloride had occurred, but it has also been true when the most careful efforts were adopted to assure complete solution of the salt.

Character of Sludge

The sludges remaining after decanting the effluents generally contained from 4 to 8 per cent solids, a great part of which was organic, and from 1 to 4 per cent fats. It was relatively easy to obtain further compacting, either by further settling and decanting, or by gentle stirring. By such simple methods sludge has been produced containing 22 per cent solids and 12 per cent fats.

The sludge dried quite readily on sand, with a rather rubbery final product containing about 50 per cent moisture. Experiments on a very small scale indicated that vacuum filtration would be feasible. Experiments also indicated that centrifuging could not be used for satisfactory concentration, apparently because the sludge is relatively low in specific gravity and is composed mainly of very fine particles.

Sludge obtained from the flotation experiments contained large amounts of air, which was fairly difficult but

not impossible to remove. Small scale experiments on both flotation and sedimentation sludge indicated that recovery of grease by acid-cracking and pressing should give grease recoveries of the same general order as on sludge from any other process, with final yield depending on the melting point of the various fatty acids present.

Cost of Coagulants

Although great quantities of calcium chloride slurry are produced as a by-product of chemical plants, the lack of evaporating facilities has made the supply of the flake form temporarily less than the demand. Present market quotations indicate a delivered cost of at least $25 per ton of technical chloride, which is about 80 per cent pure. The amount of this coagulant required in the present experiments has ranged from 0.8 to 1.8 per cent of the weight of the waste, with an average of about 1.5 per cent, equivalent to about 0.125 lb. per gallon of waste.

As reported above, for each 100 lb. of wool scoured the average amount of waste was 126 gal., which would require about 10 lb. of technical calcium chloride costing about 12½ cents (range in cost about 6 to 15 cents). It is expected that the relatively small amount of carbon dioxide required would be obtained at no cost from the most convenient stack, so that the only expense would be that of blowers and dispensers.

It seems probable that sufficient quantities of marketable grease can be recovered, even at prices somewhat below the present market, to cover at least the cost of chemicals and operation.

Limitations of Coagulation Processes

It has been pointed out above that the calcium chloride-carbonation process removes readily practically all grease and suspended solids and a great part of the suspended B.O.D., and that it had been found possible to remove also some of the dissolved B.O.D. A careful investigation of this and several coagulation methods indicates that each additional fraction of dissolved matter removed represents more and more difficulties, requires more and more skill and attention, and rapidly increases costs, so that the practical economical limit of usefulness of any coagulation process would seem to be reached when suspended matter had been removed.

If local conditions, such as the capacity of the receiving stream, demand further removal of B.O.D., biological treatment seems to offer the most economical means. Experimental trickling filters, operated with effluents from both the $CaCl_2 - CO_2$ and the hypochlorite processes, show that with a fairly high recirculation ratio and a primary B.O.D. load of about 1,200 lb. per acre-foot, highly stable effluents can be readily produced with a B.O.D. of less than 100 p.p.m. In the case of one filter an over-all B.O.D. reduction of 99.6 per cent was obtained.

Collateral Investigations

In attempting to investigate the role of the various agents in this and other processes, attempts at coagulation were made with various other chemicals. Sodium hypochlorite, in any reasonable concentration, failed to produce any coagulation or any significant reductions in B.O.D. Barium hydroxide and barium chloride were useless. It was found, however, by using carbon dioxide and very finely divided (400-mesh) calcium carbonate, mixed carefully into the waste, that satisfactory coagulation could be obtained and a clear supernatant produced. It was not found possible to use coarser forms of carbonate.

Small scale experiments have shown that the $CaCl_2 - CO_2$ process can be applied with reasonable success to wastes from laundries, tanneries and pulp and flax cooking. With the latter waste B.O.D. reductions as high as 70 per cent have been effected.

Conclusion

The use of carbon dioxide and calcium chloride, in combination, offers a reasonably simple, rapid and inexpensive method of treating wool scouring wastes. Carbon dioxide reduces significantly the amount of coagulant necessary, and its use is essential for best results. Investigations indicate that this process can be used with flotation or with sedimentation, and that workable sludge of any desired moisture content can be obtained. The process can be used to effect true precipitation as well as coagulation of suspended matter, but probably not at economical costs. The process can be applied to almost any waste high in pH and suspended matter.

OHIO RIVER VALLEY WATER SANITATION COMMISSION INAUGURATES PROGRAM

Every city of the Ohio River Basin has received notification during early January to proceed "within a reasonable time" with a sanitation program that will comply with the Water Sanitation Compact which became law in Ohio, Indiana, Kentucky, Illionis, Pennsylvania, West Virginia, Virginia and New York last July. Industries of the Ohio Valley will soon receive similar notices, although preliminary notices have already been sent some sixty firms that may have been partly responsible for recent obnoxious tastes and odors of Ohio River water.

Official copies of the Compact and a statement of policy were sent to more than a thousand municipalities up and down the valley. City officials were asked to contact local state engineers for details regarding compliance.

Four southern states have been invited to come into the Compact, including Tennessee, North Carolina, Alabama and Georgia, parts of which are in the valleys of the Cumberland and Tennessee Rivers, both tributaries of the Ohio River.

In some states steps are being taken for the introduction of supplemental legislation needed to raise minimum standards to those required by the Compact.

Offices of the Commission have been established at Cincinnati and progress is being made in arranging technical and administrative personnel. Reports received from the larger, more populous areas indicate general acceptance and compliance with the Compact program, including cities like Pittsburgh, Cincinnati, Louisville and Evansville.

Edward J. Cleary of New York City has been appointed as executive director and chief engineer of the Ohio River Valley Water Sanitation Commission. Cleary comes to this new post from the McGraw-Hill Publishing Co., where he has been executive editor of *Engineering News-Record*, weekly magazine of the civil engineering and construction industry.

A registered profession engineer, Cleary has had a broad background of technical and public relations experience in the field of sanitary and civil engineering. Following graduation from Rutgers University in 1929, he worked as field engineer on construction projects and served as a research assistant to Dr. Willem Rudolfs, chief of the New Jersey water and sewage investigation station. In 1935 Cleary became the sanitation specialist on *Engineering News-Record*.

COMPARISON OF METHODS FOR TREATMENT OF WOOL SCOURING WASTES*

By Stuart E. Coburn

Metcalf & Eddy, Boston, Mass.

Boston is one of the great wool centers of the world. More wool is scoured annually in Massachusetts than is produced in the entire United States and, in fact, over 30 per cent of the world's production is scoured in this State.

As removed from the sheep, wool contains 30 to 70 per cent extraneous matter such as dried suint, grease, sand and clay, vegetable matter, and excreta. Therefore, an average of only about 0.5 lb. of clean wool fiber is obtained per pound of grease wool. This foreign matter, when removed by detergent scouring, results in one of the most objectionable of industrial wastes. The treatment of wool scouring wastes constitutes a problem of long standing.

Methods of Scouring

The three general processes for scouring wool are outlined in the following.

Freezing Process

The freezing process for removal of dirt and grease consists of passing the wool, after dusting, through a low temperature chamber in which the moisture is frozen and the grease solidified. After freezing the dirt and fibers are separated mechanically, and the amount of organic matter to be removed by subsequent washing of the fibers thus reduced.

This is a patented process and has not been found generally acceptable as the quality of the wool after this treatment has not been considered satisfactory. One large plant, at least, which used this freezing process for a short time, has since given it up and gone back to washing with soap and soda.

Solvent Scouring

Solvent scouring consists of "opening" the wool, "dusting," and then treating the wool in batches or continuously, using solvent to remove the grease and then scouring the wool in a light soap and soda wash. The used solvent is redistilled and returned to the process and the grease recovered.

One plant has used batch solvent scouring for a number of years with profitable recovery of grease. The grease-free wastes from the detergent wash are then discharged to a nearby stream.

Recently considerable research on a semi-plant scale using solvent scouring has been carried out on removal of the grease from wool in a continuous operation. The results have been so satisfactory that the first full-sized plant is now being constructed in Pennsylvania and will be in operation this year.

Detergent Scouring

Detergent scouring or washing of the wool in a solution of soap and soda or other detergents is used almost entirely in this country.

In this method the wool is first subjected to opening and dusting, preparatory to the scouring process. Considerable dirt amounting to 5 to 15

* Presented before Division of Water, Sewage and Sanitation Chemistry, American Chemical Society, April, 1948, Chicago, Ill.

per cent of the total impurities is removed in this step and disposed of in a dry condition.

The opened and dusted wool is fed into a scouring machine and conveyed by moving rakes through two to five bowls containing a warm soap and soda solution maintained at 120° to 130° F. The first bowl in a four or five-bowl machine may be filled with warm water only and used as a desuinting bowl. The final bowl is used for rinsing and operates with a continuous flow of clean water. After rinsing the wool may be bleached, blued or carbonized before going to subsequent dyeing and finishing operations.

Wool scouring liquors are handled differently in different plants. Generally, the scouring liquor is pumped continuously or periodically countercurrent to the flow of wool, and then removed from the first scouring bowl to centrifuges where grease and dirt are removed and the centrifuge effluent returned to the scouring machine. Hoppers under the bowls, which collect sand and dirt, are dropped intermittently to waste. Complete dropping of the scouring bowl may take place over any period of from one day to one week. The desuinting bowl is usually dropped daily. These wastes, together with the continuous flow from the rinse bowl, leaks, and floor wash, make up the source of scouring liquor wastes.

Typical analyses of waste scouring liquors are given in Tables I, II, and III. Wools from different sources produce wastes of different quality, as do variations in operation of scouring trains. Carbonizing, bleaching, and blueing liquors may be included with the above wastes, thus bringing about an increase in volume and material change in character.

The volume of wastes discharged from wool scouring with detergents varies from 1,000 gal. to considerably over 2,000 gal. per 1,000 lb. of wool scoured, depending on local conditions.

Methods of Treatment of Wool Scouring Wastes

Centrifuging

Centrifuging of wool scouring liquors is practiced primarily to produce an effluent which can be re-used in the scouring process with subsequent saving of water and detergents, or for the recovery of neutral wool fat. This process removes from one-quarter to one-half of the fats determined as ether soluble matter, depending on the type of wool scoured.

The method is of little practical value for stream protection as there is little improvement in physical characteristics and the reduction of polluting matter is small.

Chlorine Treatment

Treatment of wool scouring liquors with chlorine was suggested by De Raeve as far back as 1918. The process was patented about 1925 in the United States, but has never been used commercially in this country so far as the writer knows.

Acid Cracking

Treatment by acid cracking the scouring liquors has been used for many years. The wastes first receive a short period settling in a grit chamber or "sand catcher" to remove quick settling solids. The wastes are then pumped to wooden cracking tanks where, during agitation with air, sufficient sulfuric acid is added to neutralize the alkalies, to precipitate the fats and to give an excess mineral acidity of about 1,000 p.p.m.

On quiescent sedimentation colloidal fats and soaps rise to the top as a scum or settle as a sludge, carrying with them other finely divided suspended matters. The clarified liquor between the scum and sludge is drawn to waste, with or without neutralization. The

sludge and scum are removed, consolidated and heated, then pumped to plate and frame presses where the grease is melted and pressed out of the cake for recovery. About 50 to 60 per cent of the grease, as measured by ether soluble matter, is recovered from the sludge pumped to the presses. The remaining grease is lost in the press cake. Consideration is now being given to solvent recovery of the grease in the press cake, and to solvent recovery of grease in the cracking tank sludge.

Calcium Hypochlorite Process

A process for the treatment of wool scouring wastes with calcium hypochlorite has been developed by the Fields Point Mfg. Corp. of Providence, R. I.

The treatment of wastes by this process consists essentially of adding to the warm settled wastes sufficient calcium hypochlorite to reduce the pH to about 7.5, causing coagulation and separation of the wool grease and other colloidal and suspended solids. After 8 hours of quiescent sedimentation the clarified liquor is drawn to waste. The remaining sludge and scum are thoroughly mixed by agitation, and sulfuric acid is added until the pH is reduced to between 4 and 5. The treated sludge is thereby reduced about 50 per cent in volume and the supernatant is drawn to waste. The concentrated sludge is heated by steam to 180° F. and is pressed in plate and frame presses as described under treatment by acid cracking. The recovered grease is handled in the same manner.

A pilot plant was operated a few years ago under the direction of Mr. Almon L. Fales and the writer. The wastes treated resulted from the scour-

TABLE I.—Results of Analyses of Scouring Liquor Treated by Acid Cracking

	Scouring Liquor	Final Effluent	Per Cent Reduced
Physical Examination			
Color	dec. gray-brn.	dec. buff	—
Odor	dec. sc. liquor	dec. sc. liquor	—
Suspended Matter	decided	slight	—
Turbidity	extreme	extreme	—
Chemical Results (p.p.m.)			
Residue on Evaporation:			
Total	21,360	13,170	38.3
Loss on Ignition	13,460	5,550	58.8
Fixed Residue	7,900	7,620	3.5
Suspended Solids:			
Total	11,940	1,510	87.5
Loss on Ignition	8,070	1,440	80.6
Fixed Residue	3,870	70	98.4
Acidity as $CaCO_3$	—	1,220	—
Alkalinity as $CaCO_3$:			
Total	3,150	—	—
Hydroxide	0	—	—
Carbonate	560	—	—
Bicarbonate	2,590	—	—
Fats (Ether Soluble):			
Non-acidified	7,000	—	—
Acidified	7,600	1,820	77.1
Oxygen Demand, 20°:			
Immediate	155	100	35.5
Biochemical, 5-day	3,315	1,680	49.4
Total	3,470	1,780	48.6

ing of Australian wool. This method is also being used by at least one wool scouring plant in the United States.

Calcium Chloride Process

The treatment of wool scouring wastes with calcium chloride, milk of lime or other calcium compounds has been reported many times for over 50 years. The large volume of sludge resulting from such treatment, amounting in some cases to nearly one-half of the volume of the original wastes, has been the principal reason why this treatment has not been used on a commercial scale.

During 1947 the Lawrence Experiment Station of the Massachusetts State Department of Public Health developed a modification of calcium chloride precipitation whereby the wool scouring wastes were treated with carbon dioxide from stack gases or other sources, to reduce the pH to below 8, with the addition of calcium chloride.

The resulting sludge to be treated is much smaller in volume, more compact and can be handled after conditioning with sulfuric acid in plate and frame presses for removal of the grease.

The coagulation of the wool fats and colloids is produced principally by the calcium ion, as is probably the case in the calcium hypochlorite process, and the effluent produced is similar in physical and chemical characteristics.

No full-sized plants have been constructed using this process. However,

TABLE II.—Results of Analyses of Scouring Liquor Treated with Calcium Hypochlorite

	Scouring Liquor	Final Effluent	Per Cent Reduced
Physical Examination			
Color	dec. gray-brn.	dec. amber	—
Odor	dist. sc. liquor	dist. chlorinous	—
Suspended Matter	—	—	—
Turbidity	extreme	distinct	—
Chemical Results (p.p.m.)			
Residue on Evaporation:			
Total	24,100	13,030	46.2
Loss on Ignition	14,380	4,740	70.4
Fixed Residue	9,720	8,290	14.7
Suspended Solids:			
Total	3,020*	122*	96.2
Loss on Ignition	430*	65*	85.0
Fixed Residue	2,590*	57*	98.0
pH	9.3	6.7	—
Alkalinity as $CaCO_3$:			
Total	3,800	1,320	65.4
Hydroxide	0	0	—
Carbonate	1,500	0	—
Bicarbonate	2,300	1,320	—
Fats (Ether Soluble):			
Non-acidified	5,750	—	—
Acidified	7,130	1,025	86.0
Oxygen Consumed	3,390	1,050	69.1
Oxygen Demand, 20°:			
Immediate	30		100
Biochemical, 5-day	1,770	1,040	41.2
Total	1,800	1,040	42.2

* Settleable Solids.

TABLE III.—Results of Analyses of Scouring Liquor Treated with Calcium Chloride

	Scouring Liquor	Final Effluent	Per Cent Reduced
Physical Examination			
Color	dec. gray-brn.	dec. amber	—
Odor	dec. wool sc.	dist. wool sc.	—
Suspended Matter	distinct	v. slight	—
Turbidity	extreme	slight	—
Chemical Results (p.p.m.)			
Residue on Evaporation:			
Total	30,000	15,560	48.2
Suspended Solids:			
Total	17,600	146	99.2
Settleable Solids (2 hr., %)	3.6	0.6	83.3
pH	8.8	7.6	—
Alkalinity as $CaCO_3$:			
Total	4,000	2,000	50.0
Hydroxide	0	0	—
Carbonate	800	0	—
Bicarbonate	3,200	2,000	—
Fats (Ether Soluble):			
Acidified	3,000	314	89.6
Oxygen Demand, 20°:			
Total	2,550	1,050	58.9

a number of pilot plant tests have been conducted to show what purification may be expected and to produce basic data for design of full-sized plants.

Comparison of Methods of Treatment

Tables I, II, and III show typical results obtained by treatment of scouring wastes by the three processes described above. The relative efficiencies for removals of suspended solids, fats, and biochemical oxygen demand are summarized as follows:

Treatment Process	Removal (%)		
	Acid Cracking	Calcium Hypochlorite Treatment	Calcium Chloride Treatment
Suspended solids	87.5	96.2	99.2
Fats (acidified)	77.1	86.0	89.6
5-Day B.O.D.	48.6	42.2	58.9

The method of recovering grease from the sludge produced by the three methods of treatment is similar. The acid sludge from the acid cracking process, or the acidified sludges from the calcium hypochlorite and calcium chloride treatments, are heated to about 190° F. and pressed in conventional plate and frame presses.

Treatment of wool scouring wastes by the acid cracking process under the best operating conditions produces objectionable odors which might in some cases preclude the adoption of this method. Moreover, the effluent is acid and secondary neutralization might be required before discharge into streams. The residual polluting matter, as measured by B.O.D. and by fat content, is many times that of sewage.

Calcium hypochlorite and calcium chloride treatments produce effluents similar in character. The odor question is not serious and the effluents have a pH in the range of most streams. The residual B.O.D. resulting from both treatments is usually between 800 and 1,000 p.p.m., several times as great as that of sewage. It has been found

that biological treatment on high-rate trickling filters will reduce this organic matter materially. Such filters, however, involve substantial investment, and area is not always available at an established plant.

The average results obtained over one month's operation of a high-rate trickling filter pilot plant, operating at 15 m.g.a.d. on a mixture of one volume of chemical effluent and nine volumes of recirculated trickling filter effluent, is shown in the following table:

	Wool Scouring Waste	Calcium Hypochlorite Effluent	High-Rate Trickling Filter Effluent
pH	9.2	6.0	7.0
Turbidity (p.p.m.)	5,000+	338	103
Suspended solids (p.p.m.)	5,740	284	48
Fats (ether soluble) (p.p.m.)	—	96	24
5-day B.O.D. (p.p.m.)	2,760	960	473
Nitrate nitrogen (p.p.m.)	0.0	29.6	35.0
Dissolved oxygen (p.p.m.)	0.0	1.5	9.5

The volume of sludge removed by primary settling of scouring liquors amounts to from 2 to 8 per cent by volume of the liquor. This sludge offers a distinct problem in disposal. It is foul-smelling and dries rather slowly on sludge beds because of its grease content. A practical method of disposal is to discharge this sludge to controlled lagoons. After the material is dried it can be removed by a power shovel and deposited on waste land, or used as fill.

The quantity of grease sludge produced by any of these treatments is substantial. In the case of both calcium hypochlorite treatment and calcium chloride treatment, the primary sludge can be further consolidated with sulfuric acid. The sludge produced by each of the three methods may amount to about 70 gal. per 1,000 gal. of scouring liquor treated. The sludge cake resulting from pressing may amount to about 10 per cent of the wet sludge and may be deposited on waste land.

A summary of typical sludge data is given in Table IV.

Solvent Scouring

The wastes produced by washing of solvent scoured wool may not be satis-

TABLE IV.—Sludge Data

	Acid Cracking	Calcium Hypochlorite	Calcium Chloride and Carbon Dioxide	Calcium Chloride after Acidification
Grease Sludge Produced (gal. per 1,000 gal. scouring liquor)	73	252	220	70
pH	—	7.4	7.3	3.5
Moisture (%)	—	90.4	92.9	80
Total Solids (%)	—	9.6	7.1	20
Volatile Solids, Dry Basis (%)	—	49.2	50.5	50
Fats, Dry Basis (%):				
As Collected	—	25.2	19.5	20
Acidified	—	33.2	23.4	25
Sludge Produced after Acidification (gal. per 1,000 gal. scouring liquor)	73	68	70	—
pH after Acidification	—	3.8	3.0	—

TABLE V.—Comparative Costs of Chemicals per 1000 Gal. of Scouring Liquor

	Acid Cracking		Calcium Hypochlorite Treatment		Calcium Chloride Treatment	
	Lb.	Cost	Lb.	Cost	Lb.	Cost
Sulfuric acid[1]	77	$0.77	30	$0.30	34	$0.34
Calcium hypochlorite[2]	—	—	26	1.82	—	—
Calcium chloride (flake)[3]	—	—	—	—	90	1.31
Carbon dioxide	—	—	—	—	—	Small
Total		$0.77		$2.12		$1.65

[1] At $20 per ton.
[2] At $0.07 per pound available chlorine.
[3] At $29 per ton.

factory to discharge into a stream. Preliminary investigations indicate that solvent scouring removes considerable of the suspended solids, about 85 per cent of the fats, and some 25 to 40 per cent of the B.O.D. However, the subsequent light detergent scouring produces wastes which are amenable to biological treatment.

Costs

No attempt is made to give construction costs of treatment plants under present economic conditions. The net operating costs with the various methods will vary widely depending on local conditions such as rates for labor and power and return from the sale of recovered grease. The cost of chemicals, however, make up a substantial part of the operating costs, and a comparison of estimated chemical costs for the three methods of treatment per thousand gallons of scouring liquor treated is given in Table V.

These costs are based upon treatment of different scouring liquors, although the liquors were from wools with approximately the same shrinkages. It is obvious that the cost of chemicals will vary with the strength of the scouring liquor, and that these cost figures should be considered as indicative only.

Summary

On large streams where ample dilution is available, treatment of wool scouring wastes by any of the three methods described would be satisfactory, and local conditions would be the governing factor in the selection of the method of treatment. No economical method of treatment has been developed however, which will produce an effluent comparable to those obtained by the conventional sewage treatment processes. Much additional investigation is needed.

TREATMENT OF COMPLEX CHEMICAL WASTES RESULTING FROM TANK CAR CLEANING OPERATIONS *

By G. Gutzeit

Director, Research and Testing Laboratories, General American Transportation Corp., East Chicago, Ind.

The General American Transportation Corporation owns and operates a fleet of over 38,000 tank cars, which are used to ship hundreds of various commodities. Among these are the following:

Petroleum Products—crudes, gasoline, naphtha, lubricating oils, fuel oils, etc.

Coal and Wood Tar Derivatives—pitch, phenol, cresol, creosotes, etc.

Synthetic Organic Chemicals—acetone, acetic acid, acetaldehyde, formaldehyde, methylmethacrylate, dimethylamine, ethyl chloride, vinyl acetate, chloral, styrene, etc.

Organic Solvents—ethyl alcohol, carbon tetrachloride, dichlorethylene, amyl alcohol, etc.

Liquefied Gases—ammonia, chlorine, butane, propane, dichlorodifluoromethane, methyl chloride, etc.

Inorganic Chemicals—caustic soda, sodium silicate, hydrogen peroxide, sulfur, phosphorus, phosphoric acid, sulfuric acid, muriatic acid, metallic salts, etc.

Food Products—wine, vegetable oils, syrup, fruit juices, mineral waters, soya sauce, etc.

Miscellaneous—clay, fuller's earth, stearic acid, latex, asphalt, lacquers, varnishes, fertilizers, etc.

In order to service and repair these cars, 23 maintenance shops are strategically located throughout the country. Among their functions, cleaning of the empty tanks is an important step. The technique of this operation depends obviously on the last commodity shipped, but generally involves draining, rinsing with water, steaming, and sometimes (especially in the case of certain oil cars) a hot caustic spray. The wash waters (including condensate) represent the waste of these repair plants. The exceedingly complex and variable character of this waste presents a disposal problem which is much more involved than that of any single manufacturing establishment, and is paralleled only in quality (although not in quantity) by the global sewage of some large chemical works. One of its most troublesome characteristics is the irregularity of flow and composition.

Insofar as the concentration of individual compounds is concerned, it can be stated that, on the average, petroleum products largely predominate, and that the acids generally overbalance the bases, so that the resulting liquid, after sufficient equalization, represents an oily near-emulsion with a pH below 7.0.

The original concentration varies from 100 to 1,000 p.p.m. and higher, being mainly a function of the degree of car drainage by the user and of the solubility and viscosity of the products.

Depending on the size of the shop (i.e., the number of cars to be serviced

* Presented at 1948 Spring Meeting of the California Sewage Works Association, San Diego, June 17–19, 1948.

per day), on its location (proximity of large river for dilution purposes, population, geological character of substrata, state laws, etc.) and on the commodity market in the area, the disposal process can be based on such simple means as settling and mechanical oil separation, ponding and lagooning, or will have to involve neutralization, chemical precipitation, adsorption, flotation, aeration and combinations of these operations.

The first step necessary in making a selection of methods is to determine the degree of treatment required. For that purpose, the cooperation of the local health authorities is absolutely indispensable, as hydrographic and climatic conditions, past experience, existing ordinances, etc., are crucial factors in designing the treatment unit.

Principle of Treatment Methods

In 1945, the GATC Research and Testing Laboratory was requested to work out processes for the disposal of tank car wash water in critical areas. Representative samples were collected in three plants (Sharon, Pa., East Chicago, Ind., Los Angeles, Calif.) for several weeks. A survey was made to determine the commodities most frequently shipped in each region. Experimental work, based on chemical engineering background and previous experience, resulted in the development of two different flow sheets, which were later tested on a pilot-plant scale before proceeding with the final plant design.

One of these methods utilizes an original principle, while the other represents an adaptation to local conditions of a classical procedure. In both flow sheets, the wastes are segregated according to their nature, which is relatively easy to achieve by using separate cleaning racks for tank cars having been last loaded with certain groups of materials. Wash waters polluted with oils and other immiscible organic liquids pass first through settling basins for removal of heavy sludge, then are fed to a mechanical oil separator. The overflow oil is recovered and stored for use as a fuel complement. The underflow is collected in a large equalizing basin.

From that point on, the two processes differ completely. One of them utilizes the property of fine coal to adsorb oils, phenolic compounds and most insoluble organic liquids, thereby becoming highly hydrophobic and amenable to concentration by froth flotation; the other relies on chemical co-precipitation or, more exactly, on the adsorbent properties of freshly precipitated metallic hydroxide gels.

In the first case (Figure 1), the underflow from the mechanical oil separators is adjusted to pH 4 to 5 with sulfuric acid (automatic control) and mixed in a turbo-conditioner with coal previously wet-ground to minus 50 mesh (170 lb. dry coal per 1,000 gal. waste). It is then fed to a series of Turbo-floaters. A foaming agent, such as pine oil, is added into the first cell, while the emulsified oils, fats, phenolic compounds, etc., act as collectors. The coal concentrate is thickened in a dewatering cone, and the slurry is filtered, producing a coal and oil cake (about 500 lb. per hour for a maximum daily flow of 50,000 gal. total waste) at 27 per cent moisture, which is mixed with enough dry coal to be burned under the boiler producing the steam necessary for the tank car cleaning operations. The flotation tailings, together with the neutralized waste containing soluble products, are oxidized in Turbo-aerators, in order to modify or remove any residual aromatic compounds and to reduce the B.O.D. Depending on local conditions, the final effluent is then settled in a thickener for re-use of the clear water, ponded, or directly discharged into a river.

This process (patent pending), resulting in a very good degree of puri-

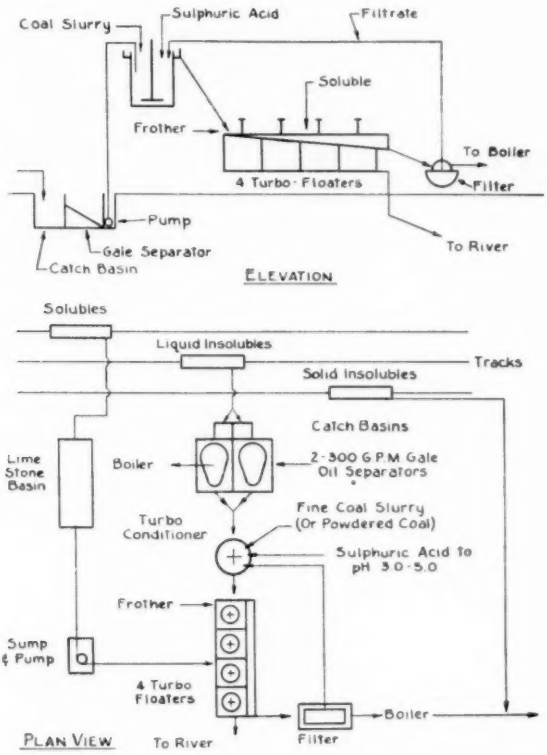

FIGURE 1.—Simplified flow sheet of coal adsorption and flotation method.

fication, is successfully applicable in the East and Middle West, where coal is available and generally used as a fuel, and where broad rivers and large bodies of water can be employed for dilution purposes. It is not suitable in Central Western California due to economic factors, local hydrographic conditions, and special requisites of pollution control.

The second flow sheet, which has been applied in the West Colton Maintenance Shop, is described below in detail. In principle, it involves segregation of alkali wastes and their evaporation in an impervious basin; mechanical separation of non-miscible liquids (oils), chemical precipitation, sludge settling, and final discharge into percolation beds.

The California Problem

With the increase on the West Coast of shipping of local products, the facilities originally operated for repair and maintenance of tank cars in Los Angeles proved inadequate. In 1946, it was therefore decided to erect a new shop, its location to be determined primarily by traffic facilities.

After examining various possible sites, a likely tract was chosen in West Colton, San Bernardino County. Due to the particular hydrographic conditions in that area, disposal of the wastes resulting from steaming and

cleaning of the tank cars prior to repair presented an especially difficult problem, as it could not be discharged into a large river for dilution purposes, and had to be ultimately fed into an underground basin which represents the main water supply of that region. Moreover, it was pointed out by local health authorities that alkali compounds could not be dissipated into the ground, regardless of concentration, as sodium salts have been proven highly objectionable to the culture of citrus fruit, due to their dispersing action on the soil particles. On the other hand, certain factors could be considered favorable: the high rate of solar evaporation (36 to 72 in. per year), the relative proximity of the Mojave Desert for "dumping" purposes, and the geological structure of the soil and subsoil, comprising a depth of 40 ft. of loose sand and an impermeable clay bed followed by various strata of gravel, sandstone, limestone and clay.

After a preliminary discussion with representatives of the California State Department of Health and the corresponding officials of San Bernardino County, the process previously studied in the Research and Testing Laboratory was adapted to meet the specifications of these authorities, and local physical and economic conditions. This experimental work and subsequent cooperation with the California State Bureau of Sanitary Engineering resulted in a setup which, although not new in basic principle, presents several interesting characteristics.

A 6-month survey of commodities

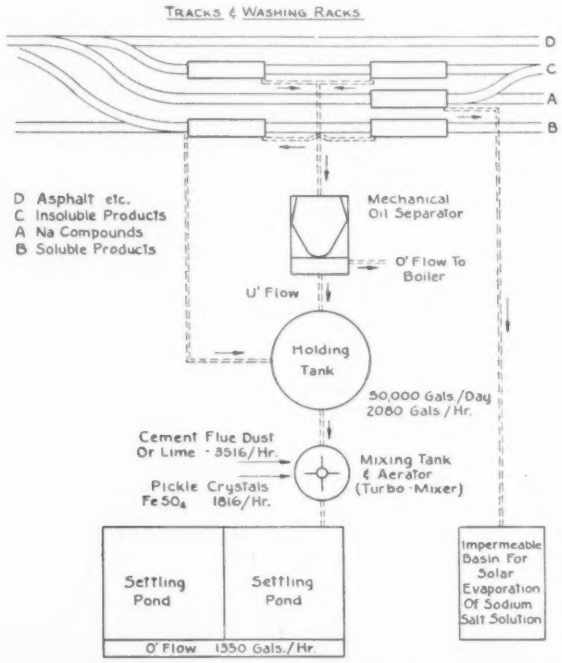

FIGURE 2.—Flow sheet (plan) of precipitation method.

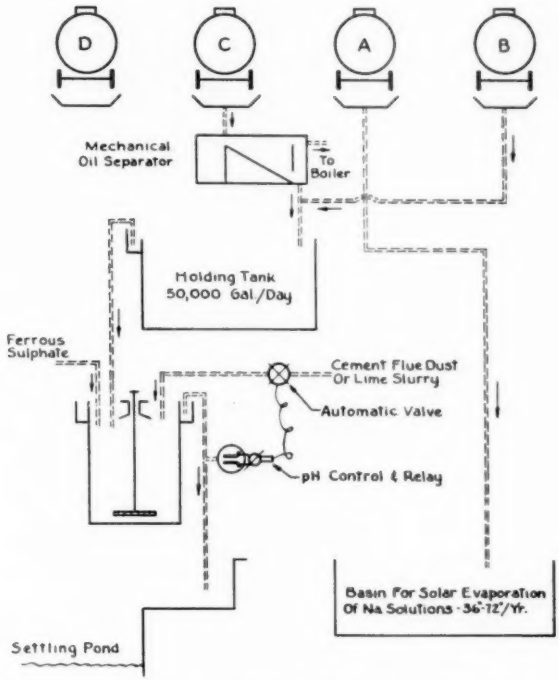

FIGURE 3.—Flow sheet (elevation) of precipitation method.

carried by tank cars in California gave the following breakdown:

3.5% Acid	6.0% Lube Oil
19.5% Asphalt	0.5% Oxygen
0.5% Butane	0.5% Silicate of Soda
5.0% Caustic Soda	1.5% Naptha
0.5% Chlorine	0.5% Syrup
11.5% Fuel Oil	11.5% Vegetable Oil
20.0% Gasoline	21.0% Wine

In the permit granted by the State Department of Health, washing of tank cars last loaded with the above products was authorized.* On the other hand, the Company made definite commitments to exclude from the cleaning operations at this plant cars having contained phenols, cresols and other aromatic or toxic substances.

Colton Waste Treatment Plant

The diversity of the above listed products obviously requires some degree of segregation. As wastes containing alkali salts cannot be treated with the other liquids, cars having last contained compounds of that nature are washed on a separate rack (Figures 2 and 3). The resulting solution is discharged into a sump, and pumped from there at a slow rate into a large, impermeable solar evaporation basin. The latter is coated with an asphaltic concrete mix. It has a flat bottom 180 ft. by 45 ft., and sloping sides 20 ft. wide (slope 1

* After successful operation of the treatment plant had started on March 1, 1948, the following additional commodities were deemed allowable: isopropyl ether, propane, ethyl alcohol, anhydrous ammonia, ethyl-methyl ketone, methyl isobutyl ketone, isopropyl alcohol, dimethyl ether, pentane, clay, fuller's earth, stearic acid, stearin, paraffin wax, hydrogen peroxide.

ft. in 20 ft.). It is surrounded by a reinforced cement curb, 16 in. high (8 ft. above ground), 9 in. wide at the bottom and 6 in. at the top, sealed with bituminous emulsion. These dimensions will permit several years of use under the most unfavorable circumstances. (The average yearly rainfall in Colton is 3.04 in.; the expected rate of evaporation is 36 to 72 in. per year.) The basin will be scraped periodically, and the accumulated solids will be dumped in the desert.

Cars having last contained asphalt, clay and similar insoluble materials, solid at ordinary temperature, are cleaned mechanically on a separate rack (Figures 2 and 3). The residue is burned or dumped, to be used eventually as fill or surfacing.

Special tanks last loaded with liquefied gases (boiling point below ordinary temperature) such as oxygen, carbon dioxide, butane, chlorine, etc., do not present any pollution problems, as these products will volatilize when the pressure is released.

Cars having been used for shipment of insoluble commodities, such as gasoline, ketones, oils (whether of vegetable or mineral origin), are cleaned over a separate flume by steaming and washing. Should a caustic spray be necessary, they are switched to the "alkali rack," where special vaporizers are used for that purpose (Figures 2 and 3). The waste flows first through two settling basins, where heavy sludge is collected, then alternately through one of two Gale mechanical oil separators (while the other can be cleaned). Most of the free non-miscible organic liquids rise to the surface in these special structures. The overflow is pumped into a tank where it is stored to produce, in admixture with standard fuel, the steam needed for the cleaning operations. The underflow from the oil separators is collected in a large covered holding basin, both for storage and equalizing purposes. The wash water from cars having last contained water-soluble commodities (with the exception of alkali compounds) is

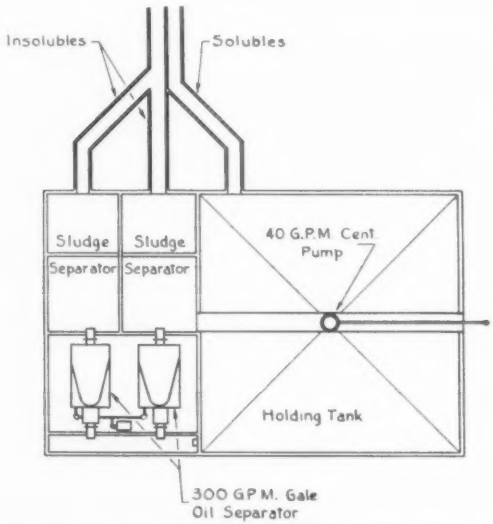

FIGURE 4.—Separators and holding tank, West Colton waste treatment plant.

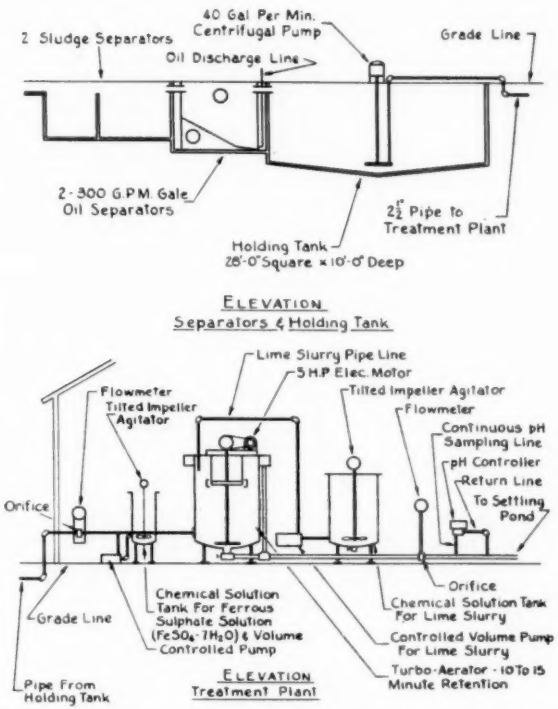

FIGURE 5.—Elevation of West Colton waste treatment plant.

also discharged into the same basin. This cement reservoir is 10 ft. deep, with a 28 ft. by 28 ft. sloping bottom (58,000 gal. capacity). At the lower end, a sump contains a 40 g.p.m. centrifugal pump controlled by a float valve (Figures 4 and 5).

As operations are presently semi-continuous, an optical and an audible signal are actuated when the liquid level reaches 2 ft. of the top. By means of an electric timer, the pump and the treatment-house equipment start automatically 25 min. after these signals. The lag is sufficient to allow checking of reagent levels and standardizing of pH electrodes. Operation stops when the liquid reaches a level 3 ft. above bottom. This arrangement is necessary to insure steady flow and avoidance of cavitation, which in turn permits constant feeding of the proper amount of primary reagent (ferrous sulfate) without use of a proportioning pump. The original project called for flow meters and proportioning pumps. Delays in delivery resulted in the present simplified system, which is less expensive and has been performing satisfactorily.

The treatment plant proper (Figure 5) is located in a corrugated steel building with elevated concrete floor. The waste is first dosed with ferrous sulfate at the maximum rate of 9 lb. per hour. This is accomplished by means of a Turbo-mixer of 49 gal. capacity, equipped with a gage, and connected to a 0 to 4 g.p.m. centrifugal pump. It has been found that addi-

tion of the reagent can be cut substantially, and at times omitted entirely, as the wastes originating in sulfuric acid cars supply more than the required amount of ferrous ion at a low pH, through the segregation of alkaline liquors.

The mixture is then fed to a Turbo-aerator of 1,200 gal. capacity (15 min. retention time), acting both as a neutralizer-precipitator and as an oxidizer. A pH flow cell (Beckman), located at the outlet of the overflow weir regulates, by means of electronic relays and an air-operated valve (Brown Instrument Co.), the amount of milk of lime (8 to 15 lb. CaO per hr.) necessary to maintain the pH above 7.2, but below 8.0. These values are continuously recorded by a Brown Control Meter.

The lime slurry is prepared and stored in a Turbo-mixer of 540 gal. capacity, equipped with a Foxboro level indicator (0 to 50 range). A Worthington 0 to 30 g.p.m. centrifugal acid resistant pump delivers the reagent to the aerator through the air-operated variable valve. A return line is provided for closed circulation.

Precipitation of ferrous hydroxide occurs around pH 6.0. This gel will entrap suspensoids, emulsified oil and other impurities. The aeration, on the other hand, achieves both transformation of the ferrous to the ferric compound and oxidation of organic materials. The excess lime is added to produce a neutral liquor, and to decrease the solubility of calcium sulfate formed by the reaction.

The suspension of ferric hydroxide is then fed into one of two large settling ponds (155 by 263 ft. each) separated by a 10 ft. dike. During the first period of operation, the water will percolate through a natural bed of 40 ft. of sand (micaceous loam), which constitutes a perfect filter medium. As time goes on, the bottom of the pond will become fairly impermeable through clogging by ferric hydroxide. Then the pond will actually act as a sedimentation basin, producing a clear overflow to be fed, by means of a variable gate and a pump located at the bottom of a sump, to a large trench (25 by 100 ft.) where it will dissipate by diffusion. This effluent will contain less than 2.126 grams of calcium sulfate per liter (maximum solubility at 25° C. and at pH 6.7).

By indirect methods the daily flow in the underground basin has been estimated to be from 46.5 to 70 m.g. This figure appears to be in fair agreement with the values obtained through different procedures by the State Division of Water Resources. Based on the average design capacity of the plant and the lowest figure for the water flow, the dilution is 1:1548. As the maximum discharge of calcium sulfate (based on saturated solution) will be 1500 p.p.m. SO_4, the highest possible increase in sulfate ion resulting from this operation can never amount to more than 1 p.p.m. In ac-

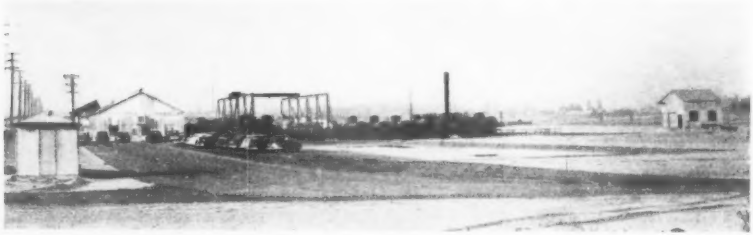

FIGURE 6.—View of West Colton plant; car washing racks in center, treatment plant at right.

tual practice, it is being kept at less than ⅓ of this figure. It can therefore be stated that the margin of safety between the present conditions and those which would represent damage to water users is very slightly decreased.

The second pond is held in reserve to permit removal of the sediments which will eventually accumulate in the first basin after several years of operation. These sediments, incidentally, can be used for surfacing. At present, evaporation and percolation take care of the total amount of treated waste. Once settling and clarification will begin, it is planned to re-use a fair proportion of the effluent for washing and hydraulic testing of tank cars. A return line and storage tank has been installed for that purpose.

A specially constructed well, which provides the water for the plant, is located in such a manner that it might serve the purpose of a "test well," and allow early detection of contamination of underground waters and easy control of the efficiency of the treatment and disposal system. Samples of well water are analyzed regularly.

The waste treatment plant (Figure 6) was designed by the GATC Engineering Department for a maximum flow of 50,000 g.p.d., with an expected average flow of 30,000 g.p.d., following flow sheet and specifications worked out by the Research and Testing Laboratories. The Turbo-aerator, reagent tanks and other processing units were built by the General American Process Equipment Division. The installation was put into operation during the first week of March, 1948, and has been running smoothly since that time.

The cost of the purification unit amounts to roughly 13.5 per cent of the total capital expenditure for the erection of the maintenance shop. This figure represents a high protection cost for the investment, and shows the Company's regard for public interests. It should be noted that the data upon which this ratio is based do not include development costs, engineering, overhead or profit on the equipment.

It is interesting to note that certain features of this setup are strictly dictated by a combination of economic considerations of local character. For instance, the use of a solar evaporation basin is only possible in a dry climate, such as that of the Southwest. The same factor is responsible for selecting large settling ponds instead of the thickener and filter originally contemplated. In areas where the yearly rainfall is high, the ferric hydroxide, charged with impurities, would have to be separated by such mechanical means.

From the preceding summary, it can be seen that each problem involving purification of industrial waste must be individually engineered. According to the nature of the waste, local availability of reagents, climatic conditions, etc., the most efficient and economical flow sheet must be worked out and soundly engineered according to properly extrapolated laboratory data obtained on average samples of the waste.

In the Colton installation, this principle has been followed, and has given the expected results.

Acknowledgment

The writer wishes to acknowledge the perfect fairness in constructive criticism and the spirit of cooperation shown by Frank M. Stead, Director, Division of Environmental Sanitation, by E. A. Reinke, Chief, Bureau of Sanitary Engineering, California State Department of Health, and his coworkers, and by L. D. Spence, Chief, Division of Sanitation, San Bernardino County Department of Health.

COMPRESSED YEAST WASTES TREATMENT *

II.—Biological Treatment in Laboratory Pilot Units

By Willem Rudolfs and Eugene H. Trubnick

In a previous paper (1) it was shown that yeast wastes, by virtue of their strength and characteristics, are inimical to chemical treatment. Electrolysis could possibly be used for pretreatment and partial recovery of some ingredients.

In further investigations, studies on anaerobic and aerobic biological methods using small units were conducted on a laboratory scale to determine the degree of purification, carbon and nitrogen changes, sludge production, gasification, and loadings under varying conditions. The amount of work done makes it impractical to present detailed results of all experiments, and the results here presented are in the nature of summarized findings with illustrations of specific conditions.

Anaerobic Digestion

Since the spent nutrient comprises about three-fourths of the total strength of the waste and constitutes about half of the total volume, experiments were conducted with this material alone, with spent nutrient mixed with wash water, and with wash water alone.

Various proportions of spent nutrient were added daily to digested sewage sludge and incubated at 30° C. Daily measurements were made of gas production, and periodic measurements made of pH, total solids, volatile solids, B.O.D., total nitrogen, ammonia and carbon.

* Journal series paper of the N. J. Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

Loadings

Low loadings were used at the start of the experiments and increased gradually to assure proper acclimatization of the organisms in the sludge to the new food material. Supernatant digested spent nutrient was decanted prior to each daily addition of fresh material.

The necessity for gradual acclimatization of the sludge was indicated by experiments where various amounts of spent nutrient were added to ripe sludge. For instance, with a daily dose of 12.5 per cent of the ripe sludge volume without previous acclimatization, as compared with gradually increased additions from 2.5 to 12.5 per cent, the B.O.D. reduction after 4 weeks of high daily additions amounted to 51 per cent, whereas with gradually increased additions the B.O.D. reduction amounted to 77 per cent with the same loading.

The effect of solids loading of properly acclimatized sludge on the reduction of solids and B.O.D., when the mixtures were subjected to quiescent conditions and periodic agitation, is graphically illustrated in Figure 1. The daily loadings are expressed in percentages of volatile matter added daily on the basis of dry volatile matter in the seed material. The curves show the relation between solids and B.O.D. reduction and gas production. Under quiescent conditions increased loadings caused a rapid decrease in effectiveness. By utilizing the same materials but agitating the mixtures for 10 min. every hour the loadings

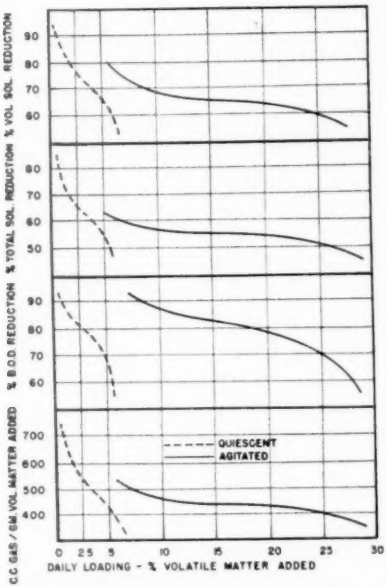

FIGURE 1.—Effect of volatile matter loading on solids and B.O.D. reduction.

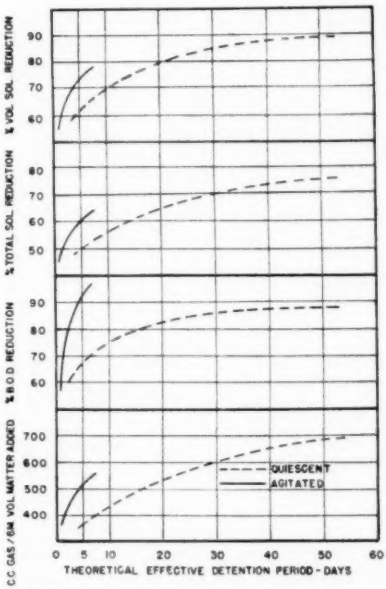

FIGURE 2.—Effect of agitation on B.O.D., volatile matter reduction and gas production.

could be increased four times with the same B.O.D. reduction and total gas production.

Of particular interest is the relation between volatile matter and B.O.D. reduction and gas production when the results are plotted against detention time (Figure 2). With agitation, about 85 per cent B.O.D. reduction was obtained in less than 3 days, whereas quiescent digestion required 25 days to produce the same results. Gas production and volatile matter reductions were about 10 per cent less. Comparison of the B.O.D. loadings in pounds per cubic foot effective digestion capacity with the pounds of B.O.D. reduced of the quiescent and agitated digestion mixtures (Figure 3) indicates clearly that not only can the loadings be materially increased by agitation, but that the efficiency is greatly increased as well. The maximum loading to obtain 75 per cent B.O.D. reduction for quiescent digestion was about 0.025 lb. B.O.D. per cu. ft. capacity, whereas with agitation the loadings could be increased to 0.12 lb. per cu. ft. for the same percentage B.O.D. reduction. The maximum loading appears to be about 5 per cent volatile matter for quiescent digestion and 22 per cent volatile matter for agitated digestion, or 0.04 lb. B.O.D. per cu. ft. digester capacity for quiescent and 0.13 lb. for agitated digestion. These loadings represent minimum theoretical detention periods of 4 days and 1 day, respectively.

Effect of Lime

Ripe sludge samples receiving 20 per cent by volume of spent nutrient daily were treated with a slurry of calcium hydroxide in doses of 250, 500, 750, and 1,000 p.p.m., respectively. Condensed average results obtained with quiescent and agitated mixtures are shown in Table I. The results show

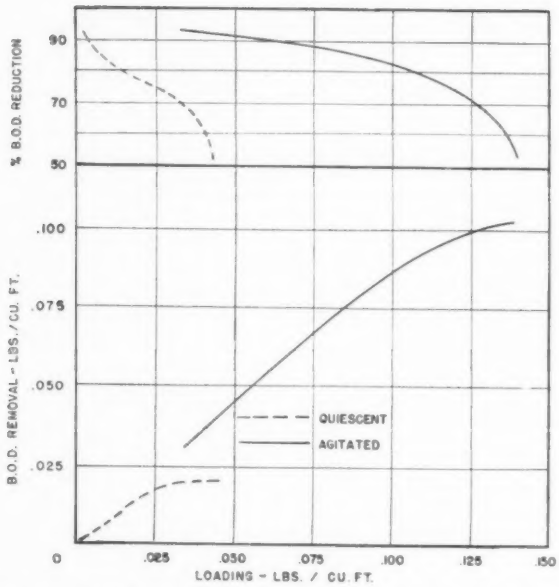

FIGURE 3.—Relation between loading and B.O.D. reduction of spent nutrient.

that no benefit was derived from the addition of lime. As could be expected the carbon dioxide content of the gases produced from the limed mixtures was somewhat lower than from the mixtures without lime, but the differences were not material. The addition of lime did not appear to affect the percentage of H_2S in the gases. The agitated mixtures produced more gas per gram volatile matter added than those digested under quiescent conditions,

TABLE I.—Effect of Lime on Digestion of Spent Nutrient

Lime Added (p.p.m.)	0	250	500	750	1,000
Quiescent					
pH	6.9	6.8	7.05	7.2	6.7
Gas (ml. per gm. v.m. added)	387	252	349	339	327
CO_2 in gas (%)	27.0	24.7	24.2	24.8	23.0
H_2S in gas (%)	1.4	2.9	1.3	1.8	1.3
Total solids reduction (%)	49	50	43	45	45
Volatile solids reduction (%)	63	63	58	59	59
B.O.D. reduction (%)	79	—	61	78	75
Agitated					
pH	7.0	6.8	7.2	7.2	6.8
Gas (ml. per gm. v.m. added)	441	339	370	444	400
CO_2 in gas (%)	25.1	25.6	23.1	24.1	22.5
H_2S in gas (%)	1.5	2.0	1.4	1.3	1.0
Total solids reduction (%)	55	54	56	55	52
Volatile solids reduction (%)	71.5	66	72	75	68
B.O.D. reduction (%)	94	—	90	91	94

and showed a materially higher B.O.D. reduction, indicating that with the same loadings gasification proceeded further. Of interest is the fact that with these relatively low loadings, B.O.D. reductions of 90 per cent or over could be obtained with agitation, whether or not lime was added.

Effect of Agitation

The results presented show that in each instance agitation of the digestion mixtures increased gasification and B.O.D. reduction. Agitation was achieved by placing the containers with digestion mixtures on a spring-supported platform, which was shaken by an eccentric gear on an electric motor. Mixtures were shaken for 1 hour immediately following introduction of the daily dose of raw material, and for 10 min. every hour thereafter. A brief summary of the average results (Table II) indicates the beneficial effects of agitation. It is of more than passing interest that an increase of about 26 per cent gas was accompanied by a 30 per cent increase in B.O.D. reduction, as compared to the 28 per cent increase in gas production from digesting sewage sludge due to agitation reported by Heukelekian (2).

In order to determine the effect of agitation on the rate of digestion (as measured by the rate of gasification) 600 ml. of spent nutrient was added to each of two 3-liter portions of sludge. One mixture served as a control, while the other was agitated as described above. Periodic gas measurements were made over a 24-hour period. Results are shown in Figure 4. With the loading used, agitation resulted in an 18 per cent increase in 24-hour gas production. The agitated sample produced as much gas in 9 hours as the control produced in 24 hours. With agitation, peak gasification occurred in 1 and 2 hours; while in the control, peak production was observed after 9 hours of incubation.

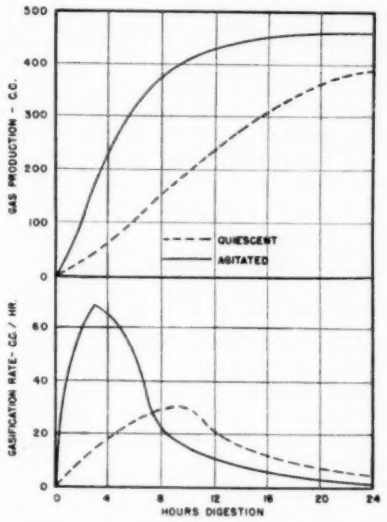

FIGURE 4.—Effect of agitation on the rate of gasification.

Carbon and Nitrogen Changes

Carbon and nitrogen changes that occur during the digestion of spent nutrients are summarized in Table III.

TABLE II.—Effect of Agitation on Digestion of Spent Nutrient

	Quiescent	Agitated	Increase (%)
Gas (ml. per gm. v.m. added)	367	482	25.9
B.O.D. removal (%)	70	91	30.0
Total solids removal (%)	49	55	12.2
Volatile solids removal (%)	61	71.5	14.7

TABLE III.—Carbon and Nitrogen Changes

	Raw	Digested
Inorganic C (p.p.m.)	108	962
Organic C (p.p.m.)	3733	883
C in gas—as CH_4 (p.p.m.)	—	1336
C in gas—as CO_2 (p.p.m.)	—	440
Total carbon (p.p.m.)	3841	3621
Organic C reduction (%)	—	76
Oxygen consumed reduction (%)	—	73
Volatile matter reduction (%)	—	68
Ammonia N (p.p.m.)	210	727
Organic N (p.p.m.)	642	125
Total nitrogen (p.p.m.)	852	852
Organic N reduction (%)	—	80

The percentage reduction of organic carbon corresponded in value to the reduction of total volatile solids and the reduction in oxygen consumed value. The drastic changes in organic carbon and nitrogen could be expected. Of more than theoretical interest is the fact that the percentage organic carbon reduction (76 per cent) is practically the same as the percentage organic nitrogen reduction (80 per cent).

Sludge Volume and Concentration

The spent nutrient contains relatively low quantities of suspended solids. It has been claimed that no increase in sludge occurs and that the sludge does not concentrate. Changes observed in the volume and concentration of sludge during 8 months' operation are summarized in Table IV. The

TABLE IV.—Sludge Volume and Solids Increase

Months in Use as Seed	0	2	7	8
Volume of sludge (liters)	5.0	4.0	3.0	3.2
Solids in sludge (%)	4.25	5.8	7.3	7.1
Weight of sludge (gm.)	213	232	219	227

sludge used at the beginning of the experiment was a typical domestic sewage sludge, containing 4.25 per cent solids. The sludge concentration gradually increased to over 7 per cent, and the sludge volume decreased by about 40 per cent as a result of compaction. Sludge volumes were determined by allowing the mixtures to settle overnight and carefully decanting the supernatant liquor. The total amount of dry sludge increased slightly. The experiment did not show whether the increase in sludge quantity was significant, but indicated that there was no reduction, and consequently no danger of loss of seed, and that the sludge build-up was probably slow. Results on large pilot plant operation will be presented in a subsequent paper.

Purification Results

A summary of results is shown in Tables V and VI to indicate what degree of purification may be expected in treating spent nutrient by anaerobic digestion at a loading between 0.08 and 0.12 lb. of raw B.O.D. per cu. ft. of digester capacity, employing agitation.

The pH of the digester effluent remained relatively constant, regardless of loading. With an average pH of 5.0 in the raw spent nutrient, digested samples had an average pH value of 7.0 (36 per cent of the digested samples with pH values between 6.7 and 6.9; 36 per cent between 7.0 and 7.2; and 28 per cent between 7.3 and 7.5), indicating a high buffer action in the sludge.

TABLE V.—Summary of Purification of Spent Nutrient by Digestion

	Raw			Digested		
	Minimum	Maximum	Average	Minimum	Maximum	Average
pH	4.5	5.9	5.0	6.7	7.5	7.0
Total solids[1] (p.p.m.)	10,490	12,150	11,630	4,540	6,830	5,340
Volatile solids (p.p.m.)	7,630	9,000	8,510	1,840	3,730	2,720
Ammonia nitrogen (p.p.m.)	150	320	243	700	800	733
Organic nitrogen (p.p.m.)	531	690	615	34	179	100
Total nitrogen (p.p.m.)	840	884	858	779	893	841
B.O.D. (p.p.m.)	2,230	4,560	3,042	163	745	391
Organic carbon (p.p.m.)	—	—	3,373	—	—	883
Sulfate (p.p.m. SO_4)	1,930	2,184	2,045	12	744	444

[1] 100 to 200 p.p.m. suspended solids.

TABLE VI.—Reduction of Constituents of Spent Nutrients, in Percentages of Original, and Gas Production

	Minimum	Maximum	Average
Total solids (%)	43	60	54
Volatile solids (%)	57	79	68
Organic nitrogen (%)	66	95	83
Organic carbon (%)	—	—	76
B.O.D. (%)	78	94	84
Sulfate (%)	63	99	80
Gas (ml. per gm. v.m. added)	400	553	474
Gas (ml. per gm. v.m. destroyed)	514	796	655
CO_2 in gas (%)	22.5	29.8	24.6
H_2S in gas (%)	1.0	2.0	1.5

Total solids in the spent nutrient were reduced by 43 to 60 per cent, and were almost entirely in solution or colloidal suspension. The raw and the digested material each contained from 150 to 250 p.p.m. suspended solids prior to settling. Volatile solids reduction amounted to 57 to 79 per cent of the original, which is materially higher than the percentage reductions obtained by digestion of sewage solids. While the dry solids of the spent nutrient contained 28 per cent ash, the ash content of the dry solids in the digester effluent amounted to 51 per cent, which is very similar to results obtained by digestion of sewage solids.

Reductions in B.O.D. varied from 78 to 94 per cent, with an average of 84 per cent, indicating that a high reduction could be obtained by digestion and that the extent of B.O.D. reduction could be regulated.

Gas was produced at the rate of 474 ml. per gram volatile matter added, or 655 ml. per gram volatile matter destroyed—a lower rate than from equivalent units of sewage solids. The CO_2 content of the gas averaged about 25 per cent, similar to gas produced from sewage solids. Despite the rather high sulfate content of the material and the high degree of sulfate reduction, the H_2S content averaged only about 1.5 per cent in the total gas produced.

Oxidation

Oxidation experiments on the raw and digested spent nutrient were conducted to determine (a) the feasibility of treating the materials by the activated sludge and trickling filter methods, (b) the general relation between B.O.D. reduction and various loadings, and (c) the changes taking place at various stages of oxidation.

Activated Sludge

Spent nutrient was mixed with an equal volume of raw settled domestic sewage and aerated. Slight clarification was observed after 10 days of aeration, and indications of sludge formation were noted after 4 weeks. The proportion of sewage in the mixture was thence decreased successively over a period of 4 weeks until the daily additions to the sludge consisted entirely of spent nutrient. No significant compacting of the sludge was observed after 5 hours' quiescent settling. Microscopic examination of the mixture showed a preponderance of *Sphaerotilus* growth, with only an occasional inactive opercularium in the field. The maximum B.O.D. removal in the spent nutrient amounted to 40 per cent of the original. It was apparent that the material could be treated by the activated sludge process, but that the aeration period required would be long.

Trickling Filter

An experimental trickling filter was constructed of three 2-ft lengths of 12-in. sewer tile filled with ripened rock from a municipal sewer plant. The filter was so constructed that samples could be obtained at 2-ft. intervals, as shown in Figure 5. Samples of digested spent nutrient were mixed with other plant effluents and diluted to various concentrations, primarily to stimulate composite wastes representative of the plant, and secondly, to stimulate various loadings beyond the limits attainable by variation of flow rates.

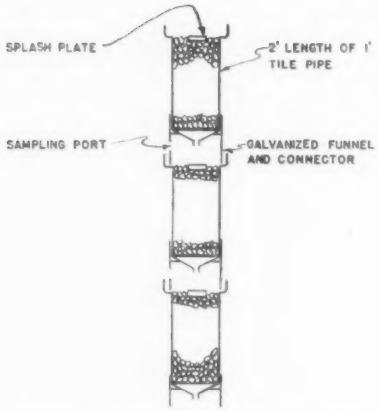

FIGURE 5.—Laboratory experimental trickling filter.

The diluted samples were fed to the filter by dripping onto a splash plate for equalization of distribution of flow. The rate of flow was maintained constantly at 1 m.g.a.d.; loadings were varied by changes in concentration, which were attained by varying the proportions of spent nutrient, wash water and dilution water in the mixtures fed to the filter.

Condensed results of B.O.D. and ammonia reduction and nitrate formation obtained with various concentrations of the digested spent nutrient-wash water mixtures are shown in Table VII. B.O.D. reduction with increased concentrations up to 400 p.p.m. was high, but dropped sharply when the concentration was increased to about 600 p.p.m. B.O.D. in the influent.

TABLE VII.—B.O.D. Reduction and Nitrification of Mixtures by Filtration

B.O.D.			NH_3-N		NO_3-N
Inf. (p.p.m.)	Eff. (p.p.m.)	Red. (%)	Eff. (p.p.m.)	Red. (%)	Eff. (p.p.m.)
256	34	87	110	85	49
277	45	84	110	60	37
306	62	80	165	56	63
397	54	86	120	60	48
591	291	51	360	44	58
662	297	55	—	—	—
734	303	59	340	32	59

There is obviously a relation between B.O.D. reduction and loading of the filter. With a small experimental unit, distribution of the influent is rather poor and results produced are not the same as those produced on a large scale where distribution is good and application continuous. However, the results give an indication of the relationship between loading and degree of purification. Of interest is the rather high degree of nitrification with all concentrations applied, indicating that with the maximum loading of 6,120 lb. per acre oxidation progressed rapidly.

The B.O.D. reductions were highest in the top 2 ft. of the filter, varying from 45 to 63 per cent with different loadings (Figure 6) as compared to 60 to 85 per cent in 6 ft. In other words, the rate of B.O.D. reduction decreased progressively through the filter.

Changes of nitrogen compounds occurring during passage through the filter are shown in Table VIII. About 43 per cent of the organic nitrogen was removed in the upper 2 ft., with no further change on passage through the next 4 ft. The rate of ammonia reduction and of nitrification accele-

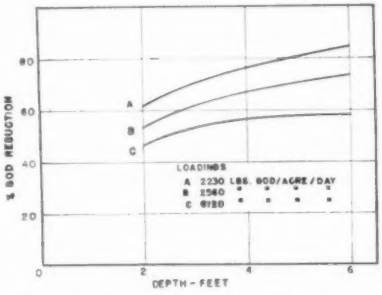

FIGURE 6.—B.O.D. reduction through filter at various loadings.

TABLE VIII.—Nitrogen Changes in Trickling Filters (Nitrogen as N)

Depth (ft.)	Org-N (p.p.m.)	NH_3-N (p.p.m.)	NO_2-N (p.p.m.)	NO_3-N (p.p.m.)	Total N (p.p.m.)
0	75	196	0	1	272
2	54	171	7	8	240
4	47	145	8	27	227
6	51	98	10	54	213

rated in passage through the filter (Figure 7). The organic nitrogen reduction amounted to 24 p.p.m. or 22 per cent, whereas the corresponding ammonia reduction amounted to 56 per cent. With a reduction of 98 p.p.m. NH_3-N, the NO_2-N and NO_3-N production amounted to 64 p.p.m. If the 24 p.p.m. reduction of organic nitrogen is assumed to result in ammonia formation, the reduction of 122 p.p.m. NH_3-N can be compared with the 64 p.p.m. of oxidized N, leaving 59 p.p.m. of the ammonia unaccounted for. Throughout the experiments, particularly during subsequent operation of a large pilot plant, a strong ammoniacal odor was present.

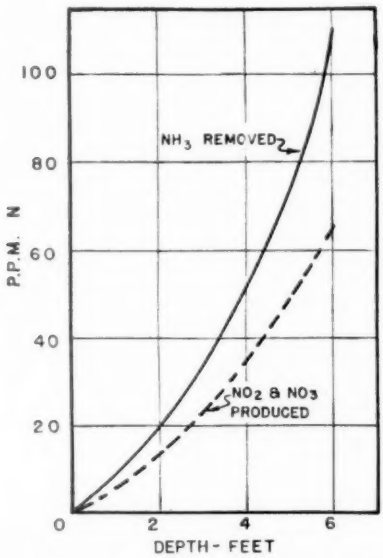

FIGURE 7.—Ammonia reduction and nitrification.

Discussion

In comparison with various physical and chemical methods of treatment, anaerobic digestion and aerobic trickling filter treatment resulted in a degree of purification high enough to warrant consideration for large scale operation. Spent yeast nutrients, the residue of a very efficient biological reaction in which the available food for the yeast has been utilized, appears readily amenable to biological action of mixed anaerobic and aerobic cultures.

The rather short detention period required for the digestion of spent nutrient is of particular interest, and is understandable in view of the fact that the organic solids are mainly dissolved and colloidal, and presumably readily available as food for mineralization by anaerobic organisms. The importance of the presumed availability of the organic matter is indicated by the effect of agitation during digestion. When the digestion mixtures are agitated sufficiently to keep the seed sludge in more constant contact with the material to be treated, destruction of organic matter proceeds to a greater extent and at a faster rate. The mechanical agitation used in the laboratory experiments can be substituted in large scale operation by a continuous flow of the waste through the digesters. Hence, instead of a batch digestion process a continuous flow process is feasible and more effective. Gas evolution, occurring in the body of the sludge because of the close proximity of the food to the organisms, would aid materially.

It is imperative, therefore, that the raw waste be effectively distributed throughout the sludge. This can readily be done by introducing the raw waste at the bottom of the digester, allowing a continuous upflow and constant ebullition of the gas. The con-

tact between seed sludge and material to be digested can be further enhanced by proper distribution of the waste into the bottom of the digester by means of a slowly rotating distributor. This could be termed a "continuous upflow" digestion process.

Since the amounts of suspended solids in the spent nutrient are small in proportion to the total B.O.D. of the liquid, the loadings on the digesters can be expressed in quantities of volatile solids or B.O.D. per unit of digester capacity. The reduction of B.O.D. is the goal, and for that reason the effectiveness of the process can be better expressed in quantities of B.O.D. per unit digester capacity. This makes comparisons with the effectiveness of trickling filters possible.

The degree of B.O.D. reduction that can be accomplished by digestion is very similar to that attained by filtration when optimum loadings are compared. When loadings are increased on both devices the percentage B.O.D. reduction decreases in a similar manner. It is possible, therefore, to obtain any desired degree of purification by combining the two methods of treatment.

The extent to which B.O.D. reduction occurs during digestion depends primarily upon the detention time or loading, and can be increased or decreased at will. In practice, the degree of B.O.D. reduction obtained in the digester will be a question of economics.

When the percentage B.O.D. reduction obtained in the digester is plotted against time, it is apparent that the reduction is more rapid during the first 24 hours. This is similar to the B.O.D. reduction obtained in the upper 2 ft. of a trickling filter. It is clear that it would be economically unsound to retain the waste over a long period in a digester, when subsequent filtration reduces the B.O.D. rapidly to the extent desired.

Examination of Figure 6 shows that a filter 4 ft. deep reduces the B.O.D. nearly to the same extent as a filter 6 ft. deep. Hence, for subsequent experimentation with a large pilot plant, filters 4 ft. deep were selected.

With the relatively high daily loadings on the filters (as compared with conventional sewage filtration) the degree of nitrification was very high. It may be assumed, therefore, that the B.O.D. loadings could be materially increased before nitrification would cease. In this respect it is of interest that considerable amounts of ammonia apparently were lost. It has been claimed that during filtration of settled sewage little or no ammonia is lost. Since the ammonia could be readily detected in the atmosphere surrounding the filter, there seems to be no question but that free ammonia was evolved from the treatment of this material.

The volumes of gas produced are directly related to the degree of B.O.D. reduction. The quantities of gas produced per gram volatile matter added or destroyed were lower than the amounts normally produced by sewage sludge. A considerable amount of gas produced from sewage sludge comes from the destruction of fats, soaps and greases (3). The fat and grease content of the spent yeast nutrient is very low, and presumably consists primarily of microbial fats or fatty acids. Volatile solids reduction of digesting sewage sludge rarely exceeds 60 per cent whereas the maximum volatile matter reduction obtained during the short digestion period of yeast waste amounted to nearly 80 per cent. The relatively low amount of gas produced was obtained by the destruction of organic matter other than grease, and in effect was higher than would be expected. Actually the amount of gas produced was about 0.5 cu. ft. per gal. of waste.

Summary

Anaerobic digestion and aerobic treatment by trickling filters of com-

pressed yeast were studied on a laboratory pilot scale. The results show that to obtain adequate and rapid digestion the sewage sludge used as seed needed gradual acclimatization. Adequate contact between seed sludge and material to be digested is necessary. This can be accomplished by mechanical agitation or by introducing the waste into the bottom of the digester by means of a rotating distribution, creating a continuous upflow and making use of the subsequent gas evolution to the fullest extent.

Lime was found to exert no beneficial effect on normally progressing digestion mixtures. Digestion for 24 hours resulted in B.O.D. reductions of 60 to 70 per cent. This represented a B.O.D. loading of 0.12 lb. per cu. ft. of digester capacity.

The B.O.D. reductions accomplished by digestion are similar to those obtained with a 6-ft. experimental trickling filter. The B.O.D. reduction varies with the loading, from 50 to 95 per cent. The volumes of gas produced are directly related to the extent of B.O.D. reduction, amounting to about 0.5 cu. ft. per gal. of spent nutrient. The composition of the gas is similar to that produced by digesting sewage solids.

Nearly all of the B.O.D. reduction occurred in the upper 4 ft. of the filter. Ammonia was lost during filtration, as indicated by assays and by the presence of ammoniacal odor in the atmosphere.

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Stream Pollution

WATER QUALITY REQUIREMENTS FOR RECREATIONAL USES*

By Albert H. Stevenson

Sanitary Engineer, U. S. Public Health Service

Increased public interest in water pollution during the past few years has resulted in active consideration of this problem by many state legislatures and in the passage of more adequate control laws by several of the states. The Commonwealth of Pennsylvania was one of the first states in recent years to adopt such measures. This interest in water pollution reached a climax with the enactment of a Federal Water Pollution Control Law and with the ratification of the Ohio River Valley Water Sanitation Compact by eight states in June, 1948.

Both of these developments should be of particular interest to the municipalities and industries in Pennsylvania. This symposium for presenting fundamentals of water pollution abatement for industry also becomes most appropriate at this time. In discussing these fundamentals it is apparent that water quality requirements for various water uses are basic. However, with the many types of water use and the large number of examinations employed to determine water quality, these requirements cannot be simplified to the extent desirable. Often the emphasis must shift from one type of water quality measurement to another with what appears to be only a moderate change in the water use. The water quality requirements for recreational uses perhaps emphasize this point the most.

* Presented at Annual Conference of the Pennsylvania Sewage and Industrial Wastes Association, State College, Pa., August 26, 1948.

Types of Recreational Use

For this discussion recreational use has been divided into three classifications. First, swimming and bathing in natural bodies of water such as lakes, ponds, streams, rivers and tidal waters, or in impounded waters such as reservoirs or lakes. Second, fishing in natural or impounded bodies of water involving as it does the sustenance, growth and propagation of the higher forms of native aquatic life. Third, boating on or camping along bodies of water used solely for boating and similar purposes.

In determining the factors which should be considered for water quality requirements for each of the types of recreational activity, it is obvious that for swimming and bathing, public health aspects are paramount. However, aesthetic considerations are also of great importance in this connection. Similarly, the support of native fish life depends upon the maintenance of a favorable physical, chemical, and biological balance in the body of water together with an absence of elements which are detrimental to fish propagation. The major considerations for the boating and camping use of water are the prevention of nuisance conditions which result in objectionable odors, floating matter, or the deterioration of the protective coatings of the hulls of floating craft.

Bathing Waters

The particular items of most importance in determining the suitability of

bathing waters for general use are freedom from concentrations of pathogenic organisms which cause illness to human beings, absence of substances which are toxic to man, and absence of objectionable visible or foul-smelling substances. There are a number of standards of bathing water quality in existence in various parts of the country. Many state health departments have adopted standards for outdoor bathing places. Furthermore, standards or limiting values of various water quality measurements have been recommended or adopted by interstate groups for the Ohio River Basin, the Tennessee River Basin, the Great Lakes and Upper Mississippi River Areas, and the Potomac River Basin, to name a few. In recommending limiting densities for bathing and recreational use in the Ohio River Basin, the results of the Winslow-Moxon studies at New Haven, Conn., and Scott's classification based upon studies of Connecticut bathing areas along the shore of Long Island Sound were used since they represented the best data then available.

All the standards have some items in common. All are based chiefly upon the bacteriological quality as measured by the density of coliform organisms. These organisms are found in the intestinal tract of man and therefore serve as an indicator of the presence of potentially pathogenic organisms. Thus the coliform group is used as a bacterial indicator of sewage pollution. However, the group also contains organisms which are found naturally in the soil. Most of the standards are based upon the correlation of bacteriological data and such chemical and observational data as are mentioned, with the sanitary survey of sources of pollution which may affect the body of water under study. The absence of toxic substances, free acids, floating solids, scum, oils, tars, grease, and preventable sludge deposits also is frequently listed.

The major points of difference in the important bacteriological requirements of the standards are primarily due to the fact that there was little or no epidemiological data available at the time most of them were adopted. Therefore, the limiting coliform densities selected were frequently those attainable in the area where surveys were being made. The coliform densities vary from a most probable number of 50 per 100 ml. in the Tennessee Valley ("Studies of the Pollution of the Tennessee River System II," TVA, 1945, p. 271) to 2,400 per 100 ml. in New York City (Board of Health Declaration of Policy dated July 9, 1948), with most standards in the 500 to 1,000 per 100 ml. range.

However, the method of arriving at this density varies considerably and significantly. In some standards it is the maximum permitted, presumably in the determination on any one sample. In others, it is the average of a series of samples, but the type of average, arithmetic or logarithmic, is not stated. In some standards an occasional overrun of the limiting concentration is permitted and in one state 20 per cent of the results may exceed 1,000 per ml. This last appears to be a realistic approach to a water quality requirement.

In the 1948 Report of Joint Committee on Bathing Places, the members of the committee representing the Conference of State Sanitary Engineers and the American Public Health Association comment as follows with regard to limiting coliform concentrations at outdoor bathing places: "It is emphasized that final classification of bathing waters should depend largely upon sanitary survey information. Bacteriological analysis findings should be used as a guide. Some areas of the country are reported to be able to meet bacterial standards for natural surface waters with maximum limits of coliform indices (as used herein) of not more than 240 to 500 per 100 ml. Such

excellent quality is, of course, greatly to be desired. However, experience indicates that other sections of the country, especially those located in more densely populated areas and among cultivated lands, cannot maintain such conditions.

"Waters showing a concentration of most probable numbers of coliform organisms of less than 1000 per 100 ml. are considered in most such areas to be fairly acceptable for bathing unless the sanitary survey discloses immediate dangers from human sewage pollution; however, it must be admitted that bathing beaches where the content of coliform organisms runs as high as 1000 per 100 ml. according to the Phelps index or 2400 per 100 ml. on the basis of most probable numbers, or sometimes even higher, have been used without reported evidence of illness, and this limit of 1000 per 100 ml. according to the Phelps index is still employed as a criterion of acceptability in some states. The trend is, of course, to reduce bacteria counts where possible by sewage treatment if human sewage is a threat, and the attainment of reasonable progress in this direction is to be hoped for. While bathing areas should always be free of visible forms of sewage matter that might contain pathogenic organisms, serious pollution may be present in many waters where treatment of sewage removes visible evidence of sewage solids but does not eliminate dangerous concentrations of bacteria."

The U. S. Public Health Service has not recommended a nationwide standard for bathing water quality although limiting coliform densities were recommended for the Ohio River Basin, as was previously noted. However, the Cincinnati Station of the Service is at present actively participating in a joint bathing water study at the southern end of Lake Michigan with the Wisconsin, Illinois and Indiana Boards of Health and with five metropolitan Chicago and Cook County agencies. Nine laboratories are cooperating in this project, the objectives of which are: (1) to determine the physical, chemical, and bacteriological quality of the waters tributary to Lake Michigan public beaches between Milwaukee, Wis., and Michigan City, Ind., (2) to study the enterococcus (streptococcus) group of organisms together with the coliform group as indicators of sewage pollution, (3) to assess the effect of the bathing load itself upon the water quality at heavily used beaches, and (4) to obtain epidemiological evidence which may lead to the development of a sound bathing water standard.

In connection with the epidemiological objective, two local beaches have been selected in Chicago for special study. Sanitary surveys of each beach are being made and samples of water are collected under various conditions of wind, weather, and temperature for bacteriological examination. Bathing load observations are made also. Adjacent population groups numbering over 1,000 families in each area and representing persons most likely to use these particular beaches are being studied. With the assistance of a small staff of field workers, each household is maintaining a daily swimming and illness record of individual members of the family for a 2-month period. It is hoped that from a review of these data at the completion of the study any significant rise in the illness incidence of swimmers above that in the non-swimmer or occasional-swimmer control group may be noted for correlation with the respective beach water qualities.

This epidemiological study in itself is a limited one and is confined to two points in one area of the country. It is believed that additional studies of this type are needed in other areas where different water quality conditions prevail and other closely built-up residential areas exist which would make such studies practicable.

It is not the purpose of this paper to suggest a standard for bathing water quality. However, it is believed that the elements which should be considered in setting up water requirements for bathing can be presented. The determinations which appear to be of most significance on the basis of present knowledge are:

(1) Bacteriological—the determination of the concentration of organisms of the coliform group, with the possibility that other groups, such as enterococcus, may furnish a valuable supplement to the coliform group.

(2) Biological—examinations indicating the absence of toxic algal blooms and cercariae.

(3) Chemical—examinations indicating the absence of toxic substances, free acids, and concentrations of chemicals which produce objectionable tastes or odors; also the presence of dissolved oxygen (several existing standards indicate that the dissolved oxygen should exceed 5.0 p.p.m.).

(4) Physical—observations indicating the absence of oils, tars, greases, scum, floating solids, and debris, except that which comes from natural sources; preventable sludge deposits; and turbidity (limiting amounts of from 10 to 250 p.p.m., except after heavy rains, have been noted in several standards). The latter item is of importance from the standpoint of safety against drowning and as a check on the effect of wave action.

In considering the suitability of bathing waters for use, it is essential that the above results, representing water quality, be correlated with the sanitary survey of potential sources of pollution and with the bathing load.

Waters Used For Fishing

Pertinent factors necessary for the sustenance of native fish life are the presence of adequate concentrations of dissolved oxygen and adequate sources of fish food in the waters, as well as the absence of organic sludge blankets which are detrimental to spawning and the absence of substances which are toxic to fish. The minimum concentration of dissolved oxygen which will support and propagate most types of native fish has been found by both the U. S. Bureau of Fisheries (Bulletin Number 22) and by the U. S. Public Health Service (Supplement F, Part II, Ohio River Pollution Control, p. 1275) in independent studies to be about 5 p.p.m., although some of the more resistant varieties will thrive at slightly lower concentrations.

In conjunction with the harvesting of shellfish which may be eaten raw, another important consideration is the bacteriological quality of overlying waters from which shellfish are taken. Since the epidemic of typhoid fever in 1924 which was traced to the consumption of raw shellfish, there has been a much greater emphasis on shellfish sanitation. The present standard for the bacteriological quality of overlying waters in approved areas is a most probable number of 70 coliform organisms per 100 ml. based upon the median of all the results at a sampling point. However, bacteriological requirements for shellfish and shellfish growing areas are not static. The U. S. Public Health Service has recently established a special laboratory at the Woods Hole Oceanographic Institution in Massachusetts for further studies on this subject.

Various water quality standards suitable for the sustenance and propagation of native fish life have been proposed or promulgated by several agencies concerned with water pollution control in the Ohio River Basin, Tennessee Valley, Potomac River Basin, streams of West Virginia, and shellfish-growing areas in coastal waters. As might be expected, these standards are not completely uniform; however, the variations in values for the several determinations are not great. The range of existing water

quality requirements for the continued maintenance of native fish life encountered in these several standards is:

Dissolved oxygen: 5.5 to 6.5 p.p.m. monthly average; 5.0 p.p.m. daily minimum.
5-day B.O.D.: 4.0 to 5.0 p.p.m. minimum observation; 1.5 to 4.0 p.p.m. monthly average; 3.0 to 6.0 p.p.m. daily maximum.
Coliform bacteria (M.P.N.)*: 70 per 100 ml. or less.
Sludge deposits: none to moderate localized.
pH: 6.5 to 8.6; 5.0 to 9.5.
Other conditions: no toxic substances, oils, tars or free acid at any time; no floating solids or debris, except from natural sources; occasional to no taste producing substances.

It will be noted that there is no measure of the quantity of fish food available. It is assumed that if the quality is brought within the limits prescribed the chemical constituents and the flora and fauna native to the water will support the fish life which is normal to the area.

Waters Used Solely For Boating And Camping

There appears to be few water quality requirements in effect which cover this particular water use. As has been mentioned, the major factors are the prevention of nuisance conditions and the protection of the coatings and hulls of floating craft from deterioration. An example of one set of standards which are applicable to this situation is the minimum quality criteria for Class D waters for streams in the Potomac River Basin, approved August 8, 1946. The criteria for Class D waters call for only the general sanitary requirement that there be no nuisance condition. The specific criteria are:

pH: 6.0 to 8.5.
5-day B.O.D.: 3.0 p.p.m. monthly average; 5.0 p.p.m. maximum observation.
Dissolved oxygen: 4.0 p.p.m. monthly average; 3.0 p.p.m. minimum daily average; 2.0 p.p.m. absolute minimum.
Other conditions: no toxic substances, oils, tars, or free acid at any time; no floating solids or debris, except from natural sources; slight localized sludge deposits allowed, if unpreventable; no offensive odors.

It will be noted in these criteria that no free acid is permitted and that the pH range is limited to prevent the occurrence of highly acid or highly alkaline waters. The limiting oxygen requirements will assure aerobic conditions and reduce the occurrence of odors. Similarly the elimination of various floating substances should make the appearance of the water acceptable from an aesthetic standpoint.

Conclusions

In this paper no attempt has been made to discuss specific industrial wastes and their effects upon the recreational uses of water. Practically all wastes, either treated or untreated, will affect one or more of the measurements used for determining quality. Furthermore, although the toxicity of many wastes has been studied, little is known of others. Then too, the discharge of particular substances to a watercourse brings up the difficult problem of limiting such discharges from individual plants sufficiently to maintain a sub-toxic level in all parts of the watercourse at all times.

In addition to further toxicity studies, it is suggested that more epidemiological studies in the vicinity of bathing areas, bacteriological research on pollution indicators, and biological investigations into the effects of microscopic plants and animals on bathers should be carried out with due regard to geographical considerations.

* For native shellfish-growing areas only.

STANDARDS OF STREAM SANITATION *

By H. W. Streeter

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In undertaking any systematic program of stream sanitation, the primary objective usually sought is the restoration of a stream to a condition suitable for certain uses common to the locality or region, or its maintenance in an existing condition of suitability for such uses. In either case, the term "suitability" for use implies a standard of sanitary condition which may be peculiar to a given use, or may meet the requirements of any one of several uses. Regardless of the type of standard adopted, or the terms in which it may be measured, its fundamental purpose is essentially the same, that is, to serve as a base line for any correctional measures which may be necessary in order to bring about, or maintain, a desirable stream condition.

Much has been written on the subject of stream standards, and opinions have varied as to what may constitute an acceptable standard for a given stream use. Some observers have stressed the importance of geographical and climatic influences on the adequacy or inadequacy of certain types of standards. Others have held the opinion that each stream is a problem in itself, and requires its own particular set of standards. Still others believe that regional standards, applicable to all natural watercourses in a given area, are both practicable and desirable. These divergent opinions are to some extent a reflection of deficiencies in scientific knowledge on the basis of which stream standards and their applicability can be judged impartially and objectively. They also suggest a certain lack of agreement on the part of administrative authorities as to the significance of the term "standards."

In the present paper, it is not intended to discuss these controversial aspects of the subject, or to devote more than a very brief space to its historical background, which has been ably covered by other writers. The present writer's purpose will be to note recent trends in standards proposed for streams in certain areas, notably in the Ohio and Potomac River Basins, and to review somewhat briefly the current status of policies and practices in the use of stream standards as indicated by the results of an inquiry recently addressed to each one of the 48 state departments of health in the continental United States.

Types of Standards

In general, standards for stream sanitation have fallen into three general categories, namely: (1) limiting stream dilution criteria, (2) standards for the treatment of wastes and quality of effluents at their points of discharge into watercourses, and (3) standards for the quality of the stream waters themselves. The type first named dates back to the year 1887, when the late Dr. Rudolph Hering, from a study of the Chicago Drainage Canal project, proposed that the minimum flow provided for diluting Chicago sewage should be not less than 150 to 200 cu. ft. per min., or 3.3 c.f.s., for each thousand persons contributing sewage. This proposal led to others of a similar nature, based largely on studies of New England streams, by Stearns, Hazen, and Goodnough, respectively. The dilution criteria recommended by these observers ranged from 2 to 6 or

* Presented at 22nd Annual Meeting, Ohio Sewage and Industrial Waste Treatment Conference, Dayton, June 23–25, 1948.

7 c.f.s. per thousand persons, Hazen introducing the significant qualification that in sluggish streams the proper dilution ratio might run as high as 10 c.f.s. per thousand persons. This type of standard has served a useful purpose as an engineering tool, though it is subject to the limitation that it considers only the volume of a stream, and takes no account of its self-purification capacity.

An early example of the second type of standard was that of the British Royal Commission, which specified that sewage and industrial effluents discharged into streams of the British Isles should contain not over 30 p.p.m. of suspended matter, or more than a concentration of oxidizible organic matter corresponding to a 5-day B.O.D. of 20 p.p.m. at 65° F. With various degrees of dilution, this requirement was modified so as to permit effluents with suspended matter as high as 150 p.p.m. when discharged into 150 to 500 volumes of water. In the United States, Pennsylvania has adopted standards for the quality of primary and secondary effluents from sewage treatment, and also for milk, oil, phenol, and coal silt wastes. This state has specified as minimum requirements for the efficiency of sewage treatment 35 per cent removal of B.O.D. for primary treatment, and 85 per cent removal for secondary treatment. The Interstate Commission for the Delaware River (Incodel) has established four stream zones according to various water uses. In Zone 2, where a relatively high standard of stream use is maintained, 85 per cent purification of all wastes is required, and in Zone 3, 50 per cent purification. The Interstate Sanitation Commission (New York, New Jersey and Connecticut) has divided the waters of the New York Metropolitan Area into two classes. For Class A waters, 60 per cent reduction in suspended solids of wastes is required, and also reduction of B.O.D. so as to produce not less than 50 per cent of dissolved oxygen saturation in the receiving water, and of coliform bacteria so as to leave not more than an average of 50 per 100 ml. in the receiving water. For Class B waters, 10 per cent reduction in suspended solids, and reduction of B.O.D. to 30 per cent dissolved oxygen saturation in the receiving water are specified. In the recently ratified Ohio River Valley Water Sanitation Compact, complete removal of settling solids, and 45 per cent removal of suspended solids, are fixed as a general minimum requirement.

The advantages of this type of standard are most apparent where local responsibility of different communities for pollution of a common watercourse cannot be equitably divided amongst them, and also where it is needed as a simple and readily interpreted means of establishing a preliminary basis of stream pollution correction. Its technical disadvantages are: (1) it affords no distinction as to the strength and character of various wastes; (2) it makes no allowance for variations in the capacities of different types of streams for dilution and self-purification; (3) it may thus tend to overcorrect in some cases, and undercorrect in others, with resulting sacrifice in economy on the one hand, or of effectiveness on the other. Its popularity among stream administrators has been due in no small measure to the fact that it sets a definite and readily measurable goal for all polluters alike, and because of these attributes, together with its impartiality, enforcement as well as persuasion are greatly facilitated. These undoubted advantages have tended to outweigh, in some cases, its technical shortcomings.

The third type of standard, which is concerned primarily with the stream itself, and with the specification of desirable qualities of its water for particular uses, has been receiving an increasing amount of attention in the United States, as well as in Europe and

South America. Permissible degrees of pollution would be regulated so as to maintain suitable stream conditions for various uses of water, both in the general interests of the public at large, and also for the needs of industry, agriculture, recreation, urban development, and other significant activities of the region concerned. Although this type of standard involves some difficult problems of evaluation and application, its advantages to the water user dependent upon streams are so great that it is becoming increasingly favored as a practical working tool, especially where stream sanitation can be handled as a regional problem. Closely associated with the stream quality standard is the idea of stream classification, or stream zoning, which recognizes practical lines of demarcation between various necessities of stream use, ranging from the highest to the lowest. One of the main disadvantages of this type of standard from the viewpoint of the individual polluter is its tendency to penalize unfavorable location on a stream, and conversely, to favor a better location, with respect to relative proximity of a source of pollution to a stream zone under pollution control. In most cases, however, this disadvantage is more apparent than real, because virtually all sources of pollution located along a stream are within the range of influence of some form of water use, and hence are subject to similar degrees of control.

The term "standard" as here used does not necessarily mean a fixed and immutable legal requirement, or established regulatory criterion, but often merely an operational goal, or objective, towards which concerted efforts to maintain or restore desirable stream conditions may be directed. In some instances, as in the recently adopted Tennessee pollution control law, legal requirements may be expressed in general terms, denoting the over-all conditions to be met by a stream or stream zone, in order to permit use of the stream for certain defined purposes, such as water supply, recreation, fish production, and so forth. In such cases, it may be left to a state or regional water authority to adopt by regulation more specific criteria of stream quality such as may be necessary in order to provide for a fair and impartial program of water sanitation, adapted to the needs of riparian dwellers. Such criteria may be subject to modification from time to time, as improvements are suggested by research and experience. They also may be faced with the necessity of legal defense, and hence must be reasonable and justifiable. Stream standards, when viewed from an administrative standpoint, are essentially temporary in their nature; hence are dynamic rather than static in their import. In some instances, notably where interstate agreements or compacts are involved, stream quality standards may become in effect legal ones, subject to amendment only by mutual agreement among the signatory authorities. Generally, however, they are subject to change by regulation, or by even less formal means.

Current State Practices in Use of Standards

A recent inquiry was addressed by the writer to each of the 48 state departments of health, requesting information as to the present status of stream standards and their use in that state. In each inquiry an expression of prevailing views was invited as to whether the use of standards, or informal working criteria, of stream quality would be desirable or otherwise from the standpoint of public opinion in the particular state, and whether any steps were being taken, in the absence of such standards or criteria, to develop them, either legally or as a matter of policy. Replies were received from 45 of the states, and except in a few instances, they have evidenced a lively interest in the subject.

Of the 45 states from which replies were received, 10 were indicated as having adopted stream standards, either by law or by regulation. In 15 other states, standards in some form are being used non-officially, thus giving a total of 25 states in which stream sanitation measures are based in some degree on the use of standards. In the remaining 20 states, the replies indicated that no standards or non-official criteria were being followed, though an active interest in establishing them was noted in eight of these states, and a total lack of interest in only two of them. In Table I, summarizing the results of the inquiry, it is further indicated that the principal water pollution control authority is exercised in 27 states by the department of health, in 16 states by a sanitary water board of pollution control commission, and in two states, by the conservation or fish and game commission. In the 25 states using stream standards, this authority is administered in 12 states by the department of health, and in 13 states by an interdepartmental pollution control body.

Table I also shows, for the 25 states using standards, a state-wide application in 14 states, and a limited area application in 11 states. Compacts or agreements embracing interstate waters are in force in 13 of the 25 states. Among this group, 22 states use mainly standards of the stream quality type, though both this and the effluent quality type are followed in eight states, and a stream classification system in a similar number of states. Where a stream classification system is followed, requirements for each class are in general varied according to the major uses to which streams are devoted. A definite and current interest in the subject of stream standards is shown in 21 states, and a future interest in 10 additional states. Of the 14 states in which a limited interest, or none whatever, is recorded, a majority are located in the more sparsely settled parts of the country, or are distinctly rural in their character. In these particular

TABLE I.—Summary of State Practices in Use of Stream Sanitation Standards
(Based on replies from 45 states)

Subject	Practice	States Included	
		Number	Per Cent of Total
Use of Standards (45 states)	(1) By law or regulation	10	22
	(2) Non-official	15	33
	(3) None	20	45
Principal Water Pollution Authority (45 states)	(1) State health department	27	60
	(2) Pollution control commission	16	36
	(3) Conservation department	2	4
Area Included (25 states)	(1) Entire state	14	56
	(2) Limited	11	44
	(3) Interstate waters	13	52
Type of Standard (25 states)	(1) Stream quality	22	88
	(2) Wastes treatment	3	12
	(3) Both (1) and (2)	8	32
	(4) Stream classification	8	32
Interest in Standards (45 states)	(1) Present-active	21	47
	(2) Future	10	22
	(3) Limited or none	14	31

cases, replies have indicated that stream pollution has not yet attained sufficient proportions to constitute a major problem.

In connection with interstate agreements and compacts, we find a more definite and uniform adherence to the principle of adopting stream standards. Among these interstate groups, standards have been adopted by the Potomac River Basin Commission, the Interstate Sanitation Commission (New York, New Jersey and Connecticut), the Interstate Commission for the Delaware River (Incodel), and the newly organized Ohio River Valley Water Sanitation Commission. Mention also should be made of the New England group of states, for which tentative standards are being drawn at the present writing. Except for the Potomac River standards, those adopted by the interstate groups above noted have tended to follow the second type previously described, with emphasis on the "percentage reduction" requirement for wastes at their points of discharge into streams.

An interesting contrast between present trends and practices in the use of stream standards is afforded by a comparison of the results of the writer's recent inquiry and those of a similar one conducted by him in 1935 for the Advisory Committee to the Water Resources Section, National Resources Board. At that time, a canvass among 25 states representing a fair cross-section of the country indicated that in only a few states were standards of any type being applied, and that none of the standards then used had any official standing comparable to that which now prevails in a few of the states. Differences of opinion concerning quality requirements for recreational and bathing waters were prevalent then, as now, and likewise as to stream conditions necessary for the maintenance of aquatic life. Definite progress appears to have been made in the crystallization of thought on this latter question, and on that of stream quality requirements for sources of water supply.

Recent Examples of Stream Standards

In view of the present trend towards the adoption of stream classification systems based on a definition of quality requirements for stream waters devoted to specified uses, it has appeared desirable in this paper to give this matter special attention. Several examples of such systems are now available, embracing most of the more common stream uses, and comprehending four distinct degrees of stream quality, ranging from excellent to unsuitable. These standards have tended to follow a similar pattern, differing mainly in details. In Table II are shown four recommended classification schemes, with references in the footnotes to their original published sources. As the recommended standards for streams of the Ohio River Basin were first in the chronological order of their development, and to some extent at least, served as a general pattern for the others, it may be desirable to consider them primarily in this discussion.

The more important characteristics of streams in the Ohio River Basin affecting their various uses were expressed in terms of coliform bacterial numbers, dissolved oxygen content, 5-day B.O.D., pH value, and the presence or absence of organic sludge deposits, toxic or taste-producing substances, oils, tarry substances, and floating solids or debris. These several elements, either singly or in combination, were considered as affording quantitative measures of a stream's suitability for water supply sources, bathing and recreation, maintenance of native fish and other beneficial aquatic life, navigation, industrial uses, and maintenance of general sanitary conditions. For "desirable" stream waters used as sources of water supply, a

monthly average coliform bacteria number not exceeding 50 per ml. (5,000 per 100 ml.) and also the absence of toxic or taste-producing substances in any degree, were considered as the most significant requirements. The limiting coliform bacterial number thus recommended was based on the results of an extensive observational and experimental study of the effi-

TABLE II.—Comparison of Four Recommended Stream Quality Standards with Classification Systems

Stream Quality and Uses	Standard*	Class	Coliforms /Ml.		D. O. (p.p.m.)		5-Day B.O.D. (p.p.m.)		pH Value		Phenols (p.p.b.)
			Ave.	Max.	Ave.	Max.	Ave.	Max.	Min.	Max.	
Excellent	Ohio R. Bas.	AA	0.5	—	—	—	—	—	6.5	8.6	—
Recreation	T.V.A.	I	0.5	—	7.0	—	1.0	2.0	6.5	8.6	—
(Bathing);	W. Va.	AA	1.0	—	7.5	6.5	0.75	1.0	6.3	7.7	0.0
Water Supplies (Chlor'n.)	Pot'c. R. Bas.	A	0.5	—	7.5	6.5	—	—	6.0	8.0	—
Desirable	Ohio R. Bas.	A	1.0	10.0	6.5	5.0	3.0	—	6.5	8.6	1.0
Recreation	T.V.A.	II	5.0	10.0	7.0	5.5	1.5	3.0	6.5	8.6	—
(Bathing and	W. Va.	A	10.0	—	6.0	5.0	2.5	3.5	5.8	9.0	5.0
Fish Life	Pot'c. R. Bas.	B	5.0	10.0	6.5	5.0	1.5	3.0	6.5	8.5	—
Desirable	Ohio R. Bas.	A	50.0	—	6.5	5.0	3.0	—	6.5	8.6	1.0
Water	T.V.A.	II	50.0	—	6.5	5.0	2.0	4.0	6.5	8.6	—
Supplies ,	W. Va.	A	10.0	—	6.0	5.0	2.5	3.5	5.8	9.0	5.0
(Filtration)	Pot'c. R. Bas.	B	50.0	—	6.5	5.0	2.0	4.0	6.0	8.5	—
Doubtful	Ohio R. Bas.	B	200.0	—	5.0	3.0	5.0	—	4.0	9.5	10.0
Water Supplies—	T.V.A.	III	200.0	—	5.5	4.0	4.0	6.0	5.0	9.5	—
Aux. Treatment;	W. Va.	B	100.0	—	4.0	3.0	6.0	7.0	3.8	10.5	25.0
Recreation; Fish Life	Pot'c. R. Bas.	C	—	—	4.0	3.0	3.0	5.0	6.0	8.5	—
			Over		*Under*	*Under*	*Over*	*Over*	*Under*	*Over*	*Over*
Unsuitable	Ohio R. Bas.	C	200.0	—	5.0	3.0	5.0	—	4.0	9.5	10.0
Water Supplies;	T.V.A.	IV	200.0	—	5.5	4.0	4.0	6.0	5.0	9.5	—
Recreation; Fish	W. Va.	C	200.0	—	3.0	2.0	6.0	10.0	3.8	10.5	25.0
Life	Pot'c. R. Bas.	D	—	—	4.0	3.0	—	—	6.0	8.5	—

* Key:

Ohio R. Bas.: Recommendations for streams in Ohio River Basin, House Document 266, Part II (page 177).

T.V.A.: Tennessee Valley Authority, "Studies of the Pollution of the Tennessee River System," 1945 (page 271).

W. Va.: West Virginia Water Commission, "Kanawha Basin Zoning Report," July, 1947 (page 22).

Pot'c. R. Bas.: Potomac River Basin Commission, Fifth Annual Report (page 22).

Remarks:

(1) Each classification specifies that no organic sludge deposits shall be present in streams of "excellent" or "desirable" qualities. For "doubtful" class, slight to moderate deposits permitted.

(2) All except Ohio River Basin classification specify limiting amounts of color and turbidity in streams of "excellent" and "desirable" quality.

(3) All classifications provide that no toxic substances, oils, tars, or free acids, floating solids, debris (except from natural sources), or taste- or odor-producing substances, shall be present in streams of "doubtful" or better quality. T.V.A. standards also provide that in such streams the water shall be free from irritation to swimmers, and that treated waters shall meet the physical and chemical characteristics of the U. S. Public Health Service Drinking Water Standards.

ciency of a representative group of municipal water filtration plants conducted by the U. S. Public Health Service several years ago (13). For the maintenance of native fish life in streams of the same class, a monthly average minimum of 6.5 p.p.m., and a daily minimum of 5.0 p.p.m., with a pH range of 6.5 to 8.6, were recommended. The daily oxygen minimum was based on the results of Ellis' extensive biological surveys of fish life in relation to water pollution (11), together with a similar biological survey of streams in the Ohio River Basin by Brinley (14) in connection with the Ohio River Pollution Survey. The results of both of these studies led to the conclusion that in order to maintain fish life in a healthy and self-propagating condition, a minimum dissolved oxygen level of 5 p.p.m. is necessary, though some varieties of fish, notably the more hardy types, can tolerate levels as low as 4 or even 3 p.p.m. under some circumstances.

As both of the above proposed standards are based on extensive and systematic scientific observations, leading to definite conclusions, their position is much firmer than that of the other standards thus far developed, though in most respects the over-all requirements listed for streams classed as "desirable" and "unsuitable" appear to be fairly reasonable in the light of general experience. The recommended bathing water standards for "excellent" and "desirable" streams in the Ohio River Basin are based on the results of the Winslow-Moxon studies of beaches in the vicinity of New Haven, Conn., together with Scott's classification of bathing waters along the shores of Long Island Sound. The latter appear to be more highly favored in other proposed standards shown in Table II, concerning which a brief discussion follows.

Of similar pattern, and deviating from the Ohio River recommendations largely in minor details, are the standards proposed by the Tennessee Valley Authority (15) and by the West Virginia Water Commission (2). The T.V.A. standards have set up four classes of waters, Class I being a Class A swimming area and suitable for water supplies with minimum treatment (chlorination). In this respect, they are similar to the Ohio and Potomac standards, Classes AA and A, respectively. Class II is divided into two groups, one being for Class B swimming waters, and the other for water supplies with normal filtration treatment. The requirements for Class II are very similar to those for "desirable" or Class A streams in the Ohio basin standards. For Class III, they follow closely those for "doubtful" or Class B streams in the Ohio River recommendations. The West Virginia standards also set up four classes of streams, Class AA being similar to T.V.A. Class I. These standards are somewhat more strict than the others with respect to requirements for sources of water supply, but are more lenient as to bathing waters, though they provide for a generally high quality of stream waters in reserved recreational areas. They permit a somewhat higher limit of phenols in streams of all classes than do the Ohio River standards. They also introduce specified limits for chlorides, fluorides, iron, color, and turbidity (not shown fully in the table). The Potomac River Basin standards list four classes—A, B, C, and D—with requirements for desirable streams closely parallel to those recommended for Ohio River Basin streams.

A noteworthy feature of all four standards is the use of the month as a time unit in fixing limiting requirements for coliform bacteria, dissolved oxygen, and B.O.D., and also the separation of these requirements according to monthly averages and daily maxima or minima. The monthly average time unit, first proposed in the Ohio River Basin standards, is in effect a stricter

requirement than an annual average, all other things being equal, but tends to narrow very materially the wide range of variations above and below the mean which in the past has introduced difficulties in the application of standards based on the annual period. Moreover, it recognizes the fact that a monthly period affords a fair basis of indicating sanitary conditions in a stream during critical times of the year with respect to various stream uses. The added specification of a daily maximum or minimum limit differing from the monthly average is desirable because critical conditions in a stream with respect to certain water uses, notably the maintenance of aquatic life and certain aspects of water supply sanitation, may occur within periods of a few hours, and must be safeguarded by setting tolerances accordingly. Thus, for desirable stream qualities, each one of the four standards listed have specified a daily minimum dissolved oxygen content of 5 p.p.m., in order to protect streams from short-time lapses in this respect which might cause serious damage to aquatic life. It has been well said that a fish dies only once, and it is a matter of common observation that extensive fish killings often occur as the result of stream conditions prevailing for relatively short periods of time. Although such mortality may be due to the temporary presence of toxic substances rather than asphyxiation due to oxygen deficiency, the principle involved is the same in both cases, and should be applicable to both of them alike, in order to be effective. In general, the tendency appears to be to specify either the total absence of certain toxic substances in streams, or their maximum allowable concentration at any time. This question has an important bearing on the fitness of streams for water supplies as well as for the maintenance of fish life.

A question may arise as to how the proper relationship between a monthly average stream characteristic and its daily maximum or minimum may be derived. In developing the Ohio River Basin recommendations, and also those of the Tennessee Valley streams, this relationship was worked out from a study of the daily frequencies with which various observed limits were exceeded, as related to the corresponding monthly average figure for the same characteristic. For example, it was found from a study of a large number of observations in different streams of the Ohio River Basin that the daily minimum dissolved oxygen content tends to remain above 5 p.p.m. when the monthly average is not less than 6.5 p.p.m. Although the findings were slightly different in this respect from the analysis of stream data covering more limited areas, such as those in the Tennessee Valley, and thus were reflected by some degree of variation in the actual figures proposed in the different standards, the method of their derivation was substantially similar in each case, judging from the information given on this point in the published reports cited in Table II.

Discussion

After considering these four sets of stream quality standards, what may be said as to their broad significance? First, it may be suggested that a desirable stream for sources of water supply should in general be suitable for sources of industrial supply, except where special requirements must be met. It also should be suitable for general recreational uses, with the possible exception of bathing purposes, which from present standards would appear to call for definitely lower densities of coliform bacteria as indicative of sewage pollution. Secondly, there is little question, in reviewing these standards, as to the main characteristics of a stream unsuitable for ordinary uses, except as a drainage channel. Thus, the recommended specifications for streams termed as

"unsuitable" in the four sets of proposed standards listed in Table II would tend to disqualify them quite definitely for domestic or industrial water supplies, irrigation or stock watering, or recreational uses of any kind, even though a stream falling into this class might not be a source of "nuisance" in the ordinary sense of this term.

Between these two categories of definitely good and definitely unsuitable are many streams or stream zones which would be classed as poor or doubtful for some uses. In this twilight zone lies much of the need for further study and possible readjustment of present stream standards. It also is possible that further study of the problems presented by standards for certain water uses, notably for bathing waters and for irrigation of raw vegetable crops, may lead to a very considerable revision of current proposals for such standards throughout their entire ranges of applicability.

The question is sometimes raised as to whether a set of stream quality standards set up in one section of the country, or in a given watershed, would be applicable in other sections or other watersheds. This would be a difficult question to answer in specific terms at the present writing, owing to the lack of adequate observational data on standards for similar water uses as applied in different parts of the country. By inference, it would appear that little, if any, modification of stream standards for certain types of water use would be necessary if applied in different regions.

An example is the minimum dissolved oxygen threshold for the maintenance of fish life, which for the same varieties of fish should not vary widely geographically, except possibly as influenced by the cumulative effects of differences in temperature and climate on fish metabolism. In warmer climates, it thus has been observed that fish life can become adjusted to somewhat lower oxygen levels than in the colder regions, this being especially true of the tropical and semi-tropical zones.

Another possible example would be standards for bathing waters, except in special cases where extraordinary precautions have to be taken to protect bathers from infections not common to other sections of the country. In other words, it might be said that the normal reaction of human bathers to toxic substances, or to water-borne disease organisms, both in a given concentration, would be expected to be about the same everywhere, except possibly as modified locally by some immunity factor peculiar to that particular region.

As regards water supply standards, different elements of them are doubtless more significant in one section than in another. For example, the need for protection of sources of water supply from certain chemically toxic substances is sometimes greater in some industrial and mining sections than in other regions. So far as bacterial standards are concerned, little evidence thus far has been disclosed, over a period of some twenty years, indicating the need for substantial modification of raw water requirements for treatment in one region as compared with other sections of the country, though it is quite possible that some degree of modification might be found desirable where wide differences in climate and mean temperature prevail. The question has been raised during the past few years as to the quantitative significance of various degrees of coliform bacteria concentration in tropical and semi-tropical regions as compared to the temperate zones. In this connection, it also should be noted that the recent trend towards the elaboration of ordinary water purification plants to include prechlorination, or improved preliminary treatment, doubtless will tend to raise their general level of bacterial efficiency, re-

gardless of geographical location, and thus to make possible the successful treatment of more highly polluted stream waters than heretofore has been considered practicable. An offsetting factor in this situation, however, is the fact that raw waters carrying a materially higher degree of sewage pollution than those which have been observed in the past to mark the upper limits of safety have been shown by experience to carry pollutional elements other than sewage bacteria which tend to increase the difficulties of producing both safe and palatable effluents for domestic and industrial uses.

Another question sometimes raised with reference to stream standards is concerned with their applicability to individual cases and situations. An example is the individual water purification plant which for various reasons may perform more efficiently than the average plant of the same type. Should a limiting standard of bacterial quality be lowered, for this reason alone, in a stream from which such a plant takes its raw water supply? Does the fact that this particular plant can handle a more highly polluted raw water than the average plant tend to vitiate the applicability of a raw water standard based on average plant performance? Should a stream standard be based on the performance of the exceptionally efficient treatment plant, rather than on that of the average plant? A careful consideration of this question from a realistic viewpoint would appear to lead to the definite conclusion that in general, stream standards must be drawn, not for the most favorable condition, but for the average, or in some case the most unfavorable situation requiring protection.

A third question sometimes raised is whether stream standards should be drawn up so as to provide desirable stream conditions, as distinguished from those which are tolerable, for various water uses. In some cases quite a wide margin of difference may exist as between "desirable" and merely "tolerable" stream qualities. The public health minded sanitarian probably could answer this question without hesitation as being favorable to aiming at desirable stream conditions in all cases where feasible. Dr. Ellis' conclusions regarding minimum dissolved oxygen levels for fish life are an interesting example of what would seem to be the rational view. He notes that some varieties of fish can survive in natural streams at oxygen levels as low as 4 or even 3 p.p.m., but in general cannot maintain themselves in a healthy state of self-propagation at levels below 5 p.p.m. From the long-range viewpoint, it seems quite obvious that the desirable 5 p.p.m. minimum is preferable to the tolerable 3 or 4 p.p.m. level.

To the public health worker, sanitation should go further than the mere prevention of disease. Under modern concepts, a positive trend towards active health promotion, rather than disease prevention alone, is the primary objective of sanitation as well as all other public health measures. This concept points clearly to the need of maintaining a desirable rather than a tolerable level of stream standards for every use of stream waters affecting the public interest, in so far as it can be accomplished at a reasonable cost to the community. It is recognized that in the absence of a clear-cut and demonstrable scientific basis for stream standards affecting certain water uses, that which Phelps (16) has defined as the "rule of expediency" usually governs the adoption of "administrative" standards, and quite properly so, as wherever reliance must be placed on opinion, however well informed, in formulating a standard, economic and physical practicability tends to become the chief guiding principle. Phelps further notes "that administrative standards are of a temporary nature and will tend to change with improve-

ments in the arts of prevention, as well as with growing appreciation of the values of health." In stream sanitation, improvements in this respect have tended to go hand-in-hand with better standards, which in some cases have followed and in others have preceeded the former.

Needs and Trends

Before concluding this paper, a few words concerning needs for further improvement of present stream standards may be desirable. Previous mention has been made of the status of bathing water standards, which need more precise definition based on well-correlated bacteriological and epidemiological evidence.

Standards for water supply uses need amplification to include limiting requirements for toxic and taste-producing chemical substances, which are finding their way into natural watercourses in increasing variety and amounts through the rapid development of new waste-producing industries.

The problem of irrigation waters is one of growing public health significance, because of the various types of salad and other raw-consumption vegetables which are being grown in irrigated fields in large areas, and shipped through interstate channels to all sections of the country. At the present time, no widely accepted standards exist for the quality of irrigation waters, or the streams from which they are drawn. Standards of streams used for other agricultural purposes, notable stock watering, need to be developed in more precise and comprehensive form. At present, opinions appear to diverge widely as to the degree of pollution which is safe for natural waters consumed by livestock. Limiting values for certain chemical pollutants which are toxic to domestic animals also need to be defined.

Stream sanitation should take account more actively of the essential and desirable qualities of stream waters for various industrial uses, in order that certain industries may be enabled to seek more favorable locations from this standpoint.

The continual search for improved water quality standards is in itself an answer to the misconception sometimes prevailing as to the possibility that the adoption of any stream standard may stultify progress and tend to "freeze" advances in this field of sanitation. On the contrary, any stream standard, whether or not it be called by that name, is a challenge to improvement, and if wisely administered will be modified from time to time as experience and further knowledge may dictate. In this respect, a close parallel is found in the manufacturing field, where improvements in product go hand in hand with better standards. The advantages of having stream standards developed and administered by state and regional water authorities acting under general laws permitting considerable latitude to these authorities are manifest, as compared with the alternative method of attempting to write detailed standards into the laws themselves, with consequent delays and legal difficulties in bringing about needed modifications and improvements. The general trend of present practice in this regard, as shown by our recent inquiry, is quite definitely in the direction of administration of stream standards through delegated authority, rather than by laws.

What may be said, in conclusion, as to the future trend of stream standards? Will they tend to become local or regional in their scope and application, or will the range of their applicability tend to become wider as their use in stream sanitation becomes more common? Will they tend to become more simplified in pattern, or more complex? These are questions which at the present writing would seem virtually unanswerable.

Despite the growing complexity of stream pollution problems, it is quite possible that future stream standards may tend to become more simplified in their major objectives, and in some respects, to be applicable to a wider range of natural waters for certain water uses than may be generally considered at this time. Aside from the influence of industrial pollution, about which much remains to be learned, the basic character of community sewage and its main components is much the same throughout the country. As previously noted, the reactions of certain water uses to stream pollutants would not be expected to vary widely, except possibly as modified by considerable differences in climatic conditions. If further experience should confirm these inferences, the applicability of stream standards would tend to be simplified and generalized, once they have been brought within the range of scientific confirmation. Meanwhile, the present trend towards the adoption of regional standards is a reasonable and healthy one, as it will tend to crystallize experience, add to general knowledge of the problem, and delineate more sharply the weaknesses of present standards and their ranges of applicability.

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THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

"NOW IS THE TIME . . ."

If a time-worn phrase may be adapted to a new purpose, "Now is the time for all good operators to start the preparation of their annual reports." It is also the time of year many sewage works men cast a jaundiced eye at the year's accumulation of operation data and wonder if an annual report is worth all of the effort required. Such a feeling is natural and desirable when contemplating a recurring task, provided all the factors concerned are evaluated objectively and honestly.

There is an "ought to" aspect to the preparation of annual operating reports which cannot be avoided. As the steward of a public investment of considerable value, every sewage works operator has a moral obligation to present to his employers, the public, an accounting of his stewardship. This moral obligation should be accepted as readily by sewage works personnel as city treasurers and other municipal fiscal agents accept their legal responsibility for submitting regular audits of their accounts.

For most operators a periodic accounting of their public trust can best take the form of an annual report which will convey a clear, understandable picture of the operation and management of the sewage works.

In addition to a public responsibility, sewage works men have an obligation to themselves to summarize, analyze, and record in usable form operation and maintenance data collected during the year. This is basic for a proper evaluation of plant performance and for a critical appraisal of current policies and practices. Preparation of an annual report provides a definite time and an added incentive for reviewing the year's work, for condensing the daily records into concise yet complete form, and for compiling an accurate "story" of plant performance during the variable conditions of the preceding year. Failure to make last year's experience readily available for solving next year's problems is an unforgivable way of wasting time and effort.

An operator's professional obligation should also be considered. Only those who have never profited from the experience of others have a right to withhold from fellow operators an accounting of their own mistakes and accomplishments. How better can experiences be passed along to the profession than through the pages of an annual report?

The annual report also provides an excellent opportunity for securing professional recognition through the Federation's annual Hatfield Awards competition. The revised rules for the awards, adopted by the 1948 Board of Control and published on page 179 of this issue of THE JOURNAL, simplify the procedure of submitting reports and provide for the review of all entries by the Federation Committee on Operation Reports, rather than by Member Association committees.

With the award competition divided into three groups, on the basis of population or population equivalent served by a plant, every sewage and industrial wastes plant operator has an equal op-

portunity to win one of the Hatfield Awards and with it the professional respect of his fellow operators.

An annual report for 1948? Yes!!! "Now is the time. . . ."

S. C. M.

IN-SERVICE TRAINING FOR EFFICIENCY AND MORALE *

By R. S. Dowey

Training Officer, Personnel Division, Department of Public Works, Los Angeles, California

The Department of Public Works of the City of Los Angeles is attempting to improve the efficiency and increase the morale of its employees. It is believed that this can be done in a great many ways, including the use of In-Service Training to accomplish these aims. Training is not the ultimate answer to the ever present problems of efficiency and morale. However, it is a very valuable tool which managements should use wherever possible to combat inefficient work performance and to raise employee morale. In order that the Los Angeles training problem may be understood, the following brief description of the Public Works Department is presented.

Department of Public Works

The Department of Public Works in the City of Los Angeles is probably typical of similar departments in other large cities throughout the country. The Department collects the garbage, takes care of the sewage, and keeps the streets in fairly good condition. There also are other responsibilities.

This organization provides for 10 large bureaus and 4 other smaller divisions. These are the Bureaus of Accounting, Assessments, Construction and Building Maintenance, Engineering, Inspection, Street Maintenance, Sanitation, Right of Way and Land, Standards, and Street Lighting. The smaller units consist of the Custodial, Garbage, Personnel, and the Telephone Exchange Divisions.

These various units employ a total of about 4,000 people who are engaged in approximately 250 different types of work, ranging from the usual clerical, laboring, and trades jobs to highly specialized technical and engineering positions.

Establishment of a Training Program

One can realize from this brief statement of the organization of the department the difficulties which would be encountered if an attempt was made to provide adequate training for all employees. Some day in the future it may be possible to give pertinent training to any employee needing it. However, the department has not been in the training business long enough yet to have reached that goal.

To many people In-Service Training means something which management has approved, and which is carried on in formal classrooms. Basically, however, training can be anything from the situation just mentioned down to the actual job situation where, for example, the foreman is demonstrating to the man under him the correct way to hold a saw. If training is considered in this manner, it must be realized that training has gone on since time began and will continue to go on indefinitely. Actually, the department has carried on formalized, management-recognized training for just a little less than a

* Presented at the 1948 Annual Meeting of the California Sewage Works Association, San Diego, Calif., June 16–18, 1948.

year. The position of Training Officer was established the latter part of July, 1947. However, before that time a great deal of informal training was done.

Earlier Employee Training

Some training has been given in the past years to many of the civil engineering employees in the Bureau of Engineering. It was designed, of course, to improve employee efficiency on the job, but it had a second purpose, which is not a part of the present day program, and that was to fit the employee to pass some of the civil service promotional examinations.

Training also has been given in the clerical field, teaching employees things they should have known before they ever went to work, such as spelling, English composition, etc. This training also was designed not only to improve the efficiency of the employee, but to help him over certain barriers that the Civil Service Department established in connection with clerical examinations.

Undoubtedly the best training that has been done in the entire department was that done in the Sewer Maintenance Division several years ago under the direction of Reuben F. Brown, Division Superintendent.

Sewer Maintenance Division Training

When a person thinks of sewer maintenance work he usually thinks of a type of work which on occasion can become very unpleasant. Such work is not always desirable. Workers are exposed to many dangerous gases, a wide variety of odors which are seldom pleasant, and germs which under certain conditions could cause a great many different diseases. In addition, sewer workers may be called out at any time of the day or night to assist in an emergency situation. In spite of all these factors, the efficiency and the morale of the employees in the Sewer Maintenance Division are higher than those of the employees in any of the other bureaus or divisions.

This is due not only to Mr. Brown's attitudes and methods of handling men under him, but also to the fact that for many years he has believed in training.

All of the Sewer Maintenance Division employees have been given a very comprehensive training program dealing with the following subjects:

Administration and Organization of the Department.
Pumping Plants: Equipment, Operation and Repair.
Planned Pipe-Line Maintenance.
Industrial Waste Methods and Practices.
How and Where Mosquitos Grow.
Methods of Timbering Excavations.
Electrical Maintenance Problems.
Disposal Plant Equipment Maintenance.
Field Tests of Sewage.
Operation and Maintenance of Activated Sludge Treatment Works.
Why In-Service Training.

Although the training was comprehensive in scope, attention was given to the actual details of each operation or function covered in each lesson.

Round-table conference subjects also were discussed, and all employees were given opportunity to participate in the discussion and to speak freely without creating any prejudice. The topics considered were:

Do the Plans, Rules, and Regulations Always Work?
Are the Policies of Plant and Equipment Maintenance and Operation Satisfactory?
Can Pipe-Line Preventive Maintenance be Improved?
What are the Important Things to Remember on Timbering Jobs?
Can Electrical Maintenance Affect Plant and Field Work?
What is Good Plant Maintenance?
How Can the Sewer Maintenance Division be Improved?

Each of these conferences was held immediately after the applicable class lecture.

Management Policies and the Need for Training

The Board of Public Works of the City of Los Angeles is wholeheartedly behind the training program. It has authorized the position of Training Officer and has provided competent clerical help. In addition, it has set up the necessary budgetary appropriation so that this training program can go on unhampered. The training officer's job is to seek needs for training, develop a program to meet those needs, and see that those programs are carried out.

Determining Training Needed

The need for an in-service training program is determined by any one or a combination of the following methods. The first method, and probably the one which is used most, consists of a directive from the head of the department, the Board of Public Works. If, in the opinion of this board, training is needed in any one of the units, it will inform the Personnel Division and the unit involved. From this point on it is the training officer's job to work with the administrator in that particular unit in setting up an outline of the course, and then train the instructors to present the material.

The second method which is used involves a request for training from a bureau or division head. When such a request is received by the Personnel Division, the training officer makes a survey of the unit and recommends to the Board of Public Works that such training be initiated. Upon receipt of its approval the training program is started.

A third method which is used involves independent research on the part of the training unit. As an example of this situation, it came to the training officer's attention that a definite need existed for safety and first-aid training within the Department of Public Works, since no formalized training in this field has been done. The staff of the training unit studied individual on-the-job injury records, covering a period of several years, to determine the type of accidents and the type of first-aid training needed. As a result of this survey a safety and first-aid instructor's training course is being prepared. Representatives from each department unit take this instructor's training course. When they have completed their studies they will be qualified as teachers in this subject and will in turn carry on instruction within their own units.

Training Courses Given Since July 1, 1947

During the past year several training programs have been initiated by one of these methods and carried to a successful completion. To give an idea of the types of programs which have been conducted, a brief description of several follow.

Construction Inspectors

A very comprehensive training program has recently been completed for construction inspectors. These men are assigned a variety of tasks. Examples of those assignments might range from the inspection of the repair of curbs or sidewalks to more complex jobs such as subdivision work, sewer line, storm drain, or sewage treatment plant construction.

Before training was started in this department it was the policy of the administrator in the Bureau of Inspection to rotate the assignments of the inspectors so that they would get basic experience in each phase of construction work. Under this plan it would take 5 years for a man to improve his over-all education through observation and experience on the job.

The training program was developed last year through consultation with the

administrator of this bureau and other people. It was believed it would accomplish much the same things as the experience type of training and would do it in a far shorter time. The training program covered a period of approximately 8 months. Two hours of instruction were given each week to sixty employees.

Of course, it is difficult to evaluate the result of any training program. This is one of the sore spots of training. But through observation of the men thus trained, through talks with their supervisors and with contractors in a good position to observe the performance of these men on the job, the department feels sure that these men have a better chance to make good than if they had had 5 years of experience on the job. It has cost approximately $500 per man for this training, but it appears certain that the city has been saved thousands of dollars in expense which would have been spread over a period of 5 years had these men been permitted to gain all of this knowledge by experience on the job.

Bureau of Standards

The Director of the Bureau of Standards for some time felt that he couldn't afford to upset the routine of the organization to engage in training because of lack of sufficient personnel to do the routine work. He recently decided, however, that the point had been reached where it was costing more not to train than it would to train. As a result, 1 to 2 hours of instruction is given each week to a number of men in that bureau, and when the training course is completed these men will be qualified and competent to conduct tests in any of the various laboratories which are set up in this bureau.

Refuse Collection

The Refuse Collection Division was having trouble with excessive truck maintenance resulting from careless clutch use. A training program was developed for all the drivers in the division. Motion pictures, models, and lectures were used in the division during the training period.

This was one training program where results could be measured. From records of clutch breakdown and repair before and after the training program, a definite improvement was found to have taken place.

The clutch training unit was followed by one on brake operation, which is being presented at this time. After the brake unit has been completed all employees will be given a basic induction training course. As employees have been hired in the past they have been told what their specific duties were, and put to work.

It is hoped that the induction training program now being prepared will give each employee a broader picture of what he is doing, why he is doing it, and how it should be done, that by this means employee efficiency and morale will be increased.

This induction training will be accomplished by means of 16-mm. color motion picture film. The Training Unit is doing all the photography and the actors, of course, are men from the Refuse Collection Division. This motion picture will follow a typical day in the work of a crew of the Refuse Collection Division. It will illustrate the various checks which must be performed before a truck and crew leave the yard, show the factors involved and precautions to be taken while driving to the pickup route, including motor vehicle provisions, sportsmanlike driving, and safety precautions to be taken when the truck arrives at the route. The picture will show methods of loading, lifting heavy containers, covering the load, etc. Position on the step and methods of distributing the load will be brought out in great detail. Of course, this film will be properly introduced by an instructor who will tell the class something of the intent of

the picture and suggest some of the main points which should be watched for in the picture. After the picture has been shown these pertinent points will be summarized to make sure that the aims of this training unit have been accomplished.

Courses in Preparation

In addition to the moving picture just mentioned, several other training programs are in preparation and are scheduled to be given to various groups of employees during the next fiscal year. The new programs will cover the fields of street lighting, safety and first aid, new employee training, and public relations.

Sewer Maintenance

The Sewer Maintenance Division has requested that its training program be carried out under three general headings and that this training be started as soon as teaching material can be prepared.

The first of these three divisions is "Operation and Maintenance of Trucks." The subject matter which will be included is apparent. Twenty men will be given a 6-hour training program covering this material. The lessons will be presented through formal class room sessions and field demonstrations.

The second unit in the Sewer Maintenance Division program will deal with the operation and repair of sewerage systems. Informative lessons covering the application of chemicals to sewage, sewer flushing, chlorinating plant operation, shop equipment use, safety regulations, pump operation and repair, pumping plant maintenance and operation, and the maintenance of electrical equipment will be presented. This program will be given to 80 employees and will involve 20 hours of instruction.

The third unit will not be presented to the employees until early in 1949, because of personnel limitations. It will deal with the general subjects of sewer cleaning as well as pipe line repair work. Included in this unit will be such topics as timbering, rodding, gas mask use, and first-aid treatment. Instruction on this material will be provided for 120 employees. Completion of this program will consume an additional 40 hours of classroom and conference time.

The training material is to be presented by means of formal classroom lessons, round table conferences, field trips to equipment and maintenance yards and jobs under construction, moving pictures, and slides.

Training Philosophy and Methods of Operation

The various programs which have been described thus far are the major ones which have been completed or are now being prepared. Several other ideas for training classes are still in the formative stages.

The fundamental thought which is kept foremost in mind in all of the training programs is this: employees are being trained for only one purpose, to save the taxpayers money. All of the training is measured against this standard. If a training program is under consideration and it is decided that its use will not save money, the program is rejected.

Since all training is for the purpose of saving the city money, the department permits all such training to be given on city time. Training is not being given for promotion, although that is a natural byproduct if the employee participates fully in the program. If promotional training is started at a later date, the employee will be required to donate part or all of the time spent in class, the exact amount depending on how much the city will benefit from such training.

If a situation exists where training must be given but the present work load of the bureau involved will not permit training on city time, the class sessions will be held on the employee's

time. When such a procedure is followed, the employee will be permitted equal time off at a later date.

Methods of Training Teachers

Past experience has proven that better teaching will be obtained by utilizing experts in the field being presented who are employed by the Department of Public Works. For example, if a lesson on the testing of concrete is to be presented, an engineer who has had a great deal of experience in this field will be obtained from the department's Bureau of Standards, and he will teach this lesson to classes for the other bureaus or divisions where such information is needed. It has been found much easier to teach a specialist the fundamental teaching techniques needed than to prepare a trained teacher to present specialized information.

In June and July of 1947 an intensive teacher-training class was conducted. Specialists in a wide variety of fields were selected from the various divisions in the department, and they were given specialized teacher-training. The men thus prepared have done substantially all of the lesson preparation and presentation which has been accomplished thus far. A similar course for teachers is now being presented, and the men being trained will be given the task of conducting classes for the training programs now in preparation.

These teacher-training classes are conducted by Commissioner Clarence J. Derrick, a member of the Board of Public Works. Commissioner Derrick has had wide experience in the engineering and educational fields and this experience, coupled with his service in the armed forces during World War II, has given him a very suitable background for this type of work. Commissioner Derrick is sold on the value of in-service training and is well aware of the many benefits which are derived from its use in city government.

Lesson Preparation and Review

Once an individual has been assigned a given subject to teach in connection with any of the training programs, it becomes his responsibility to study the subject to be presented and determine the best way to carry out his assignment. He must prepare a lesson plan form which was developed by Commissioner Derrick. After he has completed his lesson outline in this form he must present it to the Training Officer for study and evaluation. The lesson plan is further evaluated by a Board of Review which has been established for this purpose.

The Board of Review consists of five men selected from the department's bureaus. This board meets once each week and during the 1-hour session the men process all lesson plans presented for review.

After the lesson plans have been approved by the Board of Review they are reproduced and sufficient copies made so that each member of the class will receive a copy. These lesson plans, together with any notes which the employee may take or any supplementary data sheets which may be furnished, constitute a very valuable reference notebook for the employee's future use.

Size of Classes

It is a well established fact that the fewer students there are in a given class the greater is the likelihood that the training will be successful. However, there are practical limitations as to how far this principle can be carried. Obviously, if 300 men are to be trained in a given program and the decision is made to limit the classes to 10 men, it will take 30 repetitions of the same lesson to accomplish this training effort.

No attempt has been made to establish a fixed rule for the size of a class or the length of instruction time. However, it is a general policy to limit the size of classes to between 10 and 25 employees, and to limit the instruction

period to from 1 to 3 hours on any given day. Where instruction is to continue for more than 1 hour, provision is made for a break or recess during the period.

Summary

The information presented covers rather completely the accomplishments and endeavors of the Department of Public Works in the field of personnel training. There are, however, several points which should be emphasized and clarified.

First, the department is actively engaged in an in-service training program for a great many employees who are employed in many subdivisions of the department. These employees attend training classes at the direction of the department. The primary purpose of in-service training is to improve the employee's efficiency on the job and his morale. It is believed that if an employee knows what he is to do, why he is to do it, and the relationship his work has to that done by other employees in the department, he will be a better employee. He will be more content with his work, take a greater interest in that work, and be a benefit to his employer, the public.

Second, all projected training is measured with the same yardstick: "Will the application of this training course to the employees involved ultimately result in a saving of the taxpayers' money well in excess of the cost of the training?" If it will not, the training course is not undertaken.

Third, the department realizes that in evaluating the possible or actual results of any educational program, judgment must be used since frequently the immediate results are more-or-less intangible. However, there are certain objective tools, such as pre-testing and re-testing, measure of work output and amount of employee participation, which give some indication of the results of the training. In addition, subjective devices such as opinions of fellow workers, supervisors, contractors, and of the employees themselves are a fairly valid guide to the value of the training.

Fourth, it is believed that the best possible instruction can be furnished by utilizing the various experts in the employment of the department as the class leaders or teachers. Experience has proven that it is simpler to equip such an expert to be an educator than it is to make an educator into an expert.

Lastly, training is not held up as a cure for all ills. Proper administration and supervision from the top to the bottom of any organization will pay great dividends and would obviate the need for a great deal of training that now is being done in this country. Even if all businesses, industries, and public service agencies in the country were above reproach in this respect, however, the economic factors involved in training solely by supervision would necessitate the establishment of some form of in-service training. The department has proven to its satisfaction that in order to secure the maximum efficiency from its organization, the morale of the employees must be at a peak. In-service training has been found to be an economical and highly satisfactory method of accomplishing both of these aims.

IN-SERVICE TRAINING SCHEDULE FOR THE LOS ANGELES SEWER MAINTENANCE DIVISION

By Reuben Brown

Superintendent, Sewer Maintenance Division, Department of Public Works, Los Angeles, Calif.

A series of three in-service training courses are planned during 1948–49 for the employees of the Sewer Maintenance Division, Los Angeles Depart-

ment of Public Works. These courses will cover progressively the operation and activities of the Division. Participation in the training classes by employees will be voluntary and the classes will be given on city time.

Selected employees of the Department of Public Works will serve as instructors. Still pictures, motion pictures, models, field demonstrations, and other appropriate training aids will be used in presenting the subject material. Subjects which will be discussed during the training classes are as follows:

A. Maintenance and Operation of Trucks

1. Introductory Course—Motion Pictures on the Operation of Trucks and Driving Courtesy, as Practiced in the Sewer Maintenance Division.

2. Truck Driving.

3. Good Housekeeping on Trucks and Truck Appearance.

4. Field Safety Operation on Ground Surface. Using a Truck as a Tool.

5. Brake and Clutch Operation of Trucks.

6. Summary of the Operation and Maintenance of Trucks.

B. Operation and Repair of Sewerage System (Pipe Line Maintenance)

1. Introduction: Organization and Function of the Sewer Maintenance Division.

2. Extension of the Sewerage System, Showing House Connections, Pipes, Laterals, Main Lines, Trunk Lines, and Outfalls, and Their Various Relationships.

3. Field Safety Operation Below Ground.

4. Good Housekeeping and Safety in the Sewer Maintenance Division.

5. Sewer Flushing by Hand and Machine.

6. Sewer Cleaning.

7. Chemical Application for Health Protection and Odor Control.

8. Chlorination Plant Operations.

9. Maintenance of Equipment.

10. Portable Pumps and Their Operation.

11. Pumping Plants and Their Maintenance and Operation.

12. Electrical Equipment—Maintenance and Operation.

C. Repair and Operation of Pipe Lines and Sewage Treatment Plants

1. Timbering, Trenching, and Repair of Main Line Sewers.

2. Gas Masks and Their Use in Maintenance and Operation.

3. Necessary Regulations for Industrial Waste Discharge.

4. Underground Water Pollution that May Occur from Industrial Waste.

5. Daily Check and Field Tests of the Industrial Waste Section.

6. Effects of Industrial Waste on Sewage Treatment Plants.

7. The Plan and Purpose of the Hyperion Activated Sludge Plant.

8. Operation and Maintenance of Digesters in Sewage Treatment Plants.

9. Operation and Maintenance of Clarifiers.

10. Operation and Maintenance of Sludge Gas-Driven Diesel Engines.

11. Maintenance and Operation of Sludge Filters and Dryers.

12. Operation and Maintenance of Detritors and Grit Chambers.

13. Electrical System Required in the Maintenance of the Hyperion Sewage Treatment Plant.

14. First Aid Treatment for Employees of the Sewer Maintenance Division.

15. Channel Maintenance and Its Problems.

16. Summary of the Three Series of Classes.

OPERATION EXPERIENCES AT WINNIPEG*

By W. M. Scott and J. A. MacGillivray

Chairman and Engineer, respectively, Greater Winnipeg (Manitoba, Canada) Sanitary District

While the purpose of this paper is to relate experience gained in 10 years operation of the Greater Winnipeg Sanitary District sewage treatment works and not to deal with its design and construction, it is necessary in beginning to briefly refer to the chief characteristics of the sewer system and treatment plant in order that the operation experiences related may be intelligible.

The works constructed and operated by the Greater Winnipeg Sanitary District consist of an intercepting sewer system and a sewage treatment plant which collects and treats the sewage from approximately 260,000 inhabitants of the cities of Winnipeg, St. Boniface, the Town of Transcona, and the municipalities of St. Vital, East Kildonan and West Kildonan.

Intercepting Sewer System

The area tributary to the collecting system is approximately 80 sq. miles of rather level country, which is divided into three parts by the Red and Assiniboine rivers.

For collecting sewage from this area, there are 24 stations through which sewage is discharged into an interceptor which conveys it to the treatment plant. All of these stations are equipped with comminutors.

Prior to the operation of the treatment plant, the trunk sewers of Winnipeg and surrounding municipalities discharged into the Red and Assiniboine rivers. In order to collect the sewage from these trunks and convey it to a treatment plant, it was necessary to build an interceptor approximately paralleling both rivers.

Owing to the flat nature of the country and to construction difficulties, it was impracticable to lay the interceptor low enough so that all sewers could deliver into it by gravity. Consequently pumping stations became necessary at 16 locations. These pumping stations are automatic in operation.

The intercepting sewer, which is circular in shape, varies from 3.5-ft. dia. at its upper end to 7.5 ft. at its lower end. It is 7.5 miles long and is designed to carry to the treatment plant about 162 m.g.d. from a contributing population of 585,000.

Built in tunnel, the interceptor is of concrete throughout, the concrete being made of alkali-resistant cement known as Kalicrete. It receives the sewage by means of secondary sewers from 26 outlets formerly discharging directly into the rivers.

Flow Regulation

The dry weather flow from the 26 trunk sewers is diverted by dams to 24 comminutor stations where the sewage solids are cut up and screened to ¼-in. size before discharge to the interceptor. Calco automatic drainage gates permit flood water to escape to the rivers when the flow is greater than 2.75 times the dry weather sewage flow. At eight of these stations gravity flow to the interceptor is possible, the quantity of sewage intercepted being regulated by automatic float-controlled regulator gates. At the other 16 stations, pumping is necessary to raise the sewage to the secondary interceptors, from where it flows by gravity to the treatment plant.

Two relief overflow chambers on the

* Presented at the Fourteenth Annual Meeting of the Canadian Institute on Sewage and Sanitation, Niagara Falls, Ontario, Canada, Oct. 6–8, 1947.

interceptor are provided with 5-ft. control gates, permitting the flow to be bypassed to the river in the event of a shut-down at the treatment plant.

The treatment plant outfall consists of 1,572 ft. of 7 ft.-6 in.-dia. monolithic concrete pipe, plus an added 495 ft. of corrugated Armco asphalt-covered pipe which carries the effluent over unstable soil to a concrete diffuser that discharges the effluent under water to the Red River.

Sewage Treatment Plant

At the sewage treatment works the interceptor discharges into a 32-ft. dia. surge chamber at a depth of 52 ft. below ground level. From the surge chamber sewage flows into a tunnel from which it is raised to the treatment plant by low lift pumps, of 88 m.g.d. capacity, located in three pump wells in the main building.

Treatment Units

In brief, treatment consists of clarification by plain sedimentation, with sludge disposal by separate, heated digestion, elutriation, and vacuum filtration (Figure 1). Treatment to this extent is considered sufficient and in accordance with good practice and sound economics, inasmuch as there are no bathing beaches or fisheries of any value in the Red River, which receives the effluent from the treatment works, nor are any water supplies taken from the river below the plant. Provision has been made for secondary treatment, however, if future conditions should require it.

Grit Removal

The first treatment applied at the plant is the removal of grit. A grit chamber having a controlled velocity of 1 ft. per sec. is utilized for this purpose. A standby grit chamber is available but has not been provided, as yet, with collecting equipment.

Each grit chamber is 30 ft. square by 7 ft. deep. At 3.5-ft. depth, its capacity is about 24,000 gallons.

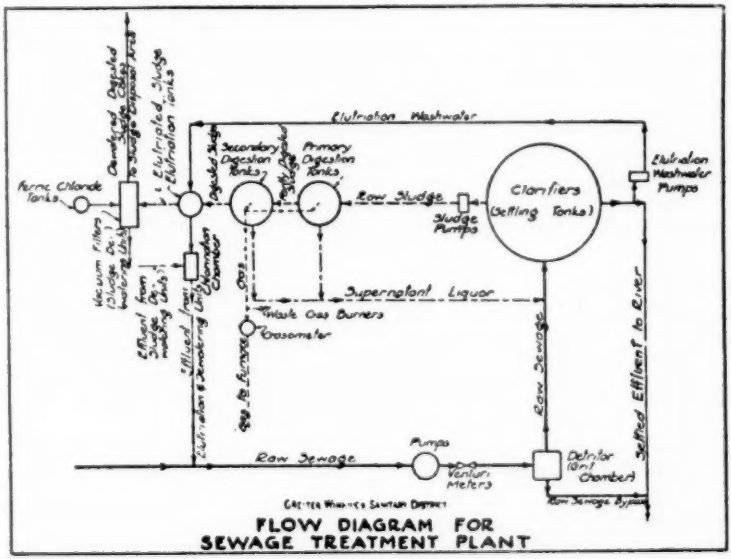


FIGURE 1.—Flow diagram of the Greater Winnipeg sewage treatment plant.

The grit after being collected and washed by a stream from a small pump is elevated into a bin, thence into a hopper outside the building. Collected grit has averaged 2 cu. ft. per m.g. Washed grit is used for fill.

Sedimentation

After leaving the grit chamber, the sewage flows through conduits to a central control chamber. Provision is made in the main building and in the central control chamber for the operators to distribute the flow to the two settling tanks or clarifier basins, each 115 ft. in dia. by 12-ft. side depth.

The retention period in these basins averages 2 hours. During 1946 suspended solids removal averaged 58.8 per cent and the B.O.D. reduction averaged 38.8 per cent.

The clarifier effluent flows over a circular weir and is discharged through the outfall sewer into the Red River.

Digesters

The sludge collected in the clarifiers is pumped to four concrete digestors, each 50 ft. in dia. by 25-ft. side depth.

The piping and control valves permit operating all four digesters as primary digesters or two as primary and two as secondary digesters. Piping flexibility is such that sludge may be drawn from or transferred to any or all of the four digesters.

Sludge Elutriation

Digested sludge is elutriated, or washed, in two steel tanks, each 22 ft. in dia. by 10-ft. side depth. Settled sewage is used as wash water. Following addition of iron salts and mixing, the sludge is dewatered by two 6-ft. dia. by 8-ft. long vacuum filters. The sludge cake is removed on a conveyor belt, weighed, and loaded on a car which travels on a trestle to the dumping point.

Operating Experiences and Observations

As coarse screening is a necessary first step in sewage treatment where combined sewers are used, the screening problem which confronted the designers of this plant was not an easy one to solve.

Ordinary screens and the accessories for their operation if provided at each of the 24 collecting stations would have resulted in a complicated set up, expensive to install and to maintain. An alternate method would have been to use non-clogging pumps, if there are such things, in the collecting stations and have all screening done at the treatment plant, but this was not believed to be practicable.

Screening by comminutors was adopted in the design and the 24 collecting stations were equipped with one each. At first various troubles developed in their operation, as might have been expected with an entirely new type of equipment. However, by making changes in the channels leading to the comminutors, by regulating the flow of sewage to them, and by improving the design of the machines themselves, which was done in 1938, this method of coarse screening has given satisfactory service when adequate inspection and maintenance has been provided.

It is difficult to compare accurately the cost of screening by the use of comminutors with that by the older bar screen method. It is probable that when results are compared, physical and financial, the balance is in favor of the comminutor. It may be said that for a situation such as that under review, the comminutor is especially suitable.

The services of 10 men and 3 trucks are now used in looking after 24 comminutors and the 16 sewage pumping stations which contain 32 centrifugal pumps and which have screened and pumped an average of 18.7 m.g.d.

This is approximately double the number of men and amount of equipment first used. It has been found that increased servicing pays as evidenced by the small number of pump cloggings referred to below.

Not all of the solids which reach the sewers, such as shoe buckles, sticks of timber, stove pipes, or pig toenails from abattoirs, pass the comminutors. Material of this kind must be removed by hand. This, of course, increases the amount of servicing required.

Pumps—Collecting System

The sewer collecting system has 32 vertical low lift electric motor-driven pumps located in 16 stations. About half of these gave satisfactory service from the beginning, but the others did not. The chief cause of trouble was the rags in the sewage.

To reduce the amount of clogging trouble, all hospitals were instructed to keep rags out of the sewage. The shrouded type pump impellers in about six lift stations were changed from four to three blades, with blunt inlet edges. The comminutors received more attention and their teeth were kept sharp. As a consequence, in 1946 there was a total of only 14 pump cloggings, and these occurred in 9 of the 32 pumps operating.

Pumps—Main Building

In the main building of the sewage treatment plant, there are six sewage pumps. These are electric motor-driven centrifugals having a total capacity of about 87.5 m.g.d. They are not of the non-clogging type. In 1946 the pumps required cleaning a total of 469 times, 77 being the maximum number of cleanings during any one month.

Rags which have been shredded by the comminutors and have reached the interceptor collect in balls and remain in the interceptor until an increase in the flow brings them to the pumps. When one of these balls of rags enters a pump impeller, the operator is very soon aware of the fact because of noise. When this happens, the pump must be shut down and the rags removed by hand. At times rags also wrap around the impeller, gradually reducing its capacity. Occasionally, by closing the pump discharge valve the changed hydraulic condition within the pump results in setting free the rags.

Less rag trouble has been experienced with the smaller pumps, those having a capacity of about 2.4 m.g.d., than with the larger pumps of 36 m.g.d. capacity.

Pumps—Sludge

The sludge pumps used at Winnipeg are of the scru-peller type and are especially adapted for sludge pumping. They are in part positive and in part centrifugal in action. The pumps originally installed were replaced by others of the same type having greater capacity and power. These latter pumps have given complete satisfaction. All sludge pumps should have ample capacity and power for the work they have to do.

Digesters

The digesters, which had a design capacity of slightly more than 1 cu. ft. per capita, were operated until 1941 as two primary and two secondary units. Experience has shown that the digesters do not have sufficient capacity. Since 1942 they have all been gradually changed to primary operation. Two of the digesters have turbo-mixers consisting of a vertical shaft carrying three impellers and supported by a roller bearing on the digester roof and a guide bearing on a 3-ft. high concrete base built on the digester floor.

The lower bearing as installed did not last long because of the gritty material which worked into it. The bearing installation was improved by placing a grease seal on top of the lower bearing. A ¼-in. pipe was extended from the grease seal to a point outside the digester from which a pressure gun

can be used to force grease into the bearing daily. With this improvement, the bearing now lasts about 2 years.

The merit of the turbo-mixer is that it breaks up floating solids and releases the gas. Such mixers are a desirable accessory for any sludge digester.

Because of increased solids in present day sewage, e.g. rags, fibrous material from manufacturing processes, paunch manure, and household garbage ground up by units installed for that purpose in kitchen sinks, the digester capacity as designed is undoubtedly low and experience at Winnipeg indicates that not less than 2.5 to 3 cu. ft. per capita capacity is desirable.

With further regard to digester capacity, the following is quoted from the chemists report in the 1942 Summary of Plant Operations for the Winnipeg plant: "It was found that there was quite a marked difference between different sludges and as the alkalinity was fairly constant, this difference appeared to be due to the varying fibre or silt content of the various sludges. . . . The results show a variation of from 0.7 per cent to 3.5 per cent ferric chloride demand and it was observed that the lower ferric chloride requirements (for sludge conditioning prior to dewatering by vacuum filtration) were usually associated with a coarse fibrous content such as crushed straw or hay in the digested sludge. Because of the coarser solids in the less digested sludges, the primary digesters sludges often show improved filtering properties."

The conclusion to be drawn is that rather than trying to eliminate all fibrous materials from the sludge, provision should be made for sufficient digester capacity to handle a certain amount of such material.

Elutriation

It has long been realized that the ultimate disposal of solids, especially organic solids, removed from the sewage is a major problem in all treatment plants. Elutriation or washing of the digested sludge is one of the newer steps in sludge conditioning which has been practiced for about 12 years and has amply proved its value. The Greater Winnipeg Sanitary District was the first in Canada to use the elutriation process.

By effective washing, alkalinity is reduced, the quantity of ferric chloride required is reduced to ⅓ or ¼ of what it would be without elutriation, and the vacuum filters are enabled to operate more efficiently. The experience of 10 years operation of the Winnipeg plant is in full agreement with a conclusion stated by McNamee (1): "Digested sludge elutriated by countercurrent washing with 2.5 volumes of water can be conditioned with ⅓ the amount of ferric chloride."

A conservative estimate of the saving in ferric chloride effected by elutriation at Winnipeg is not less than $40,000, and this despite overloading and other unfavorable conditions attending operation of the elutriating tanks. Ample elutriating capacity pays high dividends. It promotes good plant operation and reduces the cost of vacuum filtration.

Vacuum Filtration of Digested Elutriated Sludge

In the operation of the Winnipeg vacuum filters, the average quantity of ferric chloride used for sludge conditioning has been 3 per cent of the dry solids, by weight, produced. There is no doubt that with less overloading of the digesters and elutriating units, a much smaller percentage of ferric chloride usage would have resulted.

Filter cake is dropped from the filters on to a belt conveyor, weighed and discharged to an automatic dump car which carries it by means of a trestle to the stock pile. It has cost $9,483.73 during 8 years to remove the sludge cake from underneath the

trestle to open ground. This removal is at the rate of 32.6 cents per cu. yd. and is gradually becoming less as market gardeners and others haul practically all the cake away for soil conditioning, preferably after it has been moved from underneath the trestle.

Gas Production and Utilization

The average quantity of digester gas produced has been about 1 cu. ft. per day per capita contributing population. Approximately 20 per cent of the gas produced was utilized in heating the digesters and treatment works buildings, the remainder being wasted.

To waste 183,000 cu. ft. of gas per day seems an economic sin. In the plant design provision was made for gas engines to use the surplus gas to develop electric power. The fact that the Hydro Electric Department of the city of Winnipeg offered a power rate of 0.625 cents per kw.-hr. caused the Administration Board to accept this quotation and defer installation of gas engines perhaps indefinitely. This appears to have been a wise decision and is supported by the later experience that there is a three-week period in the spring when the sewage is so dilute that barely enough gas is produced for heating requirements. During this period the engines would have to be converted to use of fuel oil, if gas was used for power purposes. This factor places the balance in favor of the present arrangement for power.

Engineers, however, do not rest easily under the knowledge of waste and many proposals for the use of this wasted gas have been made, but none yet adopted. The latest proposed the use of waste gas is in the firing ovens of a new brick and tile manufacturing plant located about a quarter of a mile from the sewage plant.

Average content of the gas has been as follows:

Methane (CH_4)	66.9%
Carbon dioxide (CO_2)	32.3%
Other	0.8%
B.t.u. per cu. ft.	635

Sewer Gas Hazards

No underground chamber of any kind located on ordinary city streets should be considered safe for a man to enter until its atmosphere is first tested by means of detectors for explosive gases, carbon monoxide, hydrogen sulfide, etc. Such structures which form part of a sewerage system are particularly dangerous. Therefore, use of the best and most complete equipment for testing, for ventilating, and for rescue is imperative.

During the first 6 months of operation, maintenance of the comminutor and pumping stations was carried on with a modest force of 3 men, 2 trucks, and a small amount of equipment. It was soon realized how inadequate this was. The maintenance crew was soon increased. Each truck was provided with a portable blower to supply fresh air; fresh air masks with hose and manifold to connect to blower; detectors for H_2S, CO, and explosive mixtures; and a safety harness with ropes.

Nevertheless, in 1942 the lives of two operators, both young and vigorous men, were lost. This accident occurred in a comminutor chamber, the most troublesome and dangerous one of the 24. One man was overcome; the second went to his rescue. A third narrowly escaped. They were poisoned probably by hydrogen sulfide or carbon monoxide.

It is difficult to warn men effectively against such dangers until a tragedy impresses it on them. Oxygen deficiency detectors have been added to the safety equipment. Operators are under strict discipline as to testing and the use of all safety equipment. The most modern equipment and methods should be the minimum requirement for maintenance work of this nature.

Industrial Wastes

Industrial wastes, particularly those from abattoirs and meat packing plants, have been the cause of trouble

and expense both in the sewage collecting system and in the treatment plant. No major difficulties were experienced with wastes from breweries, creameries or tanneries.

There are four meat packing plants, four abattoirs, and three horse abattoirs contributing sewage and wastes for treatment and disposal. These have a killing capacity of 16,000 animals per day. This present load has grown steadily since 1937.

Before the era of sewage treatment in Winnipeg, all the wastes of all industries went to the rivers by way of the sewers with practically no control exercised, although municipal laws existed for that purpose. Such a habit is difficult to change. Prohibition of such abuse of the sewer system should be one of the major preparations prior to the introduction of sewage treatment. Also, a careful study of the quantity and quality of industrial wastes, with as accurate a forecast as possible of their increase, should be made before a design is undertaken.

A certain amount of willingness, but not much enthusiasm, has been shown by industrial managers to prevent objectionable materials going to the sewers. Devices for such prevention have invariably been left to the plant engineer. It has not been realized yet that the design of these units calls for a specialist just as does the design of all other parts of industrial plants.

Two classes of wastes have been found to be potential trouble makers: (1) solids or semi-solids such as grease, paunch manure, bones, hides, hair, rags, etc.; and (2) liquids of high B.O.D. The former class of wastes should be excluded from the sewers and disposed of by the producer. The latter class should be subject to a special charge for their treatment; otherwise treatment is being accomplished at the expense of others.

Damage to Concrete by H_2S

Disintegration of the surface of the concrete in the walls and piers of the outfall sewer chamber was first noted in the fall of 1940. Observations were made by test patches and were continued until in 1946 it was plain that repair or renewal could not be postponed longer with safety.

Hydrogen sulfide was believed to be the source of acid which was attacking the concrete.

Sewage enters the discharge chamber from different directions and at varying elevations, resulting in excessive turbulence in the flow. The areas where destructive action was most severe were located in a pattern strongly suggestive of the area on which the sewage spray fell.

Extent of Concrete Disintegration

Investigations included examinations of the disintegrated concrete scale and determinations of the amount of hydrogen sulfide carried by the sewage.

Deterioration of the concrete surface, which extended from 1½ to 4 in. in depth, produced a gravel and putty-like mixture of slightly greater volume than the concrete it displaced. The swelling caused the mixture to bulge and sag, and in some places to slough off.

Samples of the putty-like material was stirred with distilled water and tested for pH. One sample had a pH of 3.2; another a pH of 4, which was extremely acid for the circumstances. Visual examination of the scale showed acid corrosion of the carbonate stones. Chemically, the mixture showed a very high sulfate content; some limestones were nearly all replaced by calcium sulfate, which identified the acid attack as due to sulfuric acid. There was no sign of attack below the water line in the chamber as the sewage contains alkaline buffers which would neutralize any mild acid production with which it came into contact.

Action of Sulfides

The spray droplets from the sewage besides containing carbon dioxide, carbonate residues, and ammonium compounds, which combinations could produce mild acid conditions by mold action, also contain some dissolved sulfides and some decomposable organic residues, including sulfur-bearing proteins. The spray carries dissolved surplus compounds and, in dampening the concrete surface, provides a moisture film for solution of gaseous hydrogen sulfide.

The process whereby sulfuric acid is produced has not been investigated here but others have identified several reasonable biological means whereby quite strong concentrations can be formed from sulfur in various chemical combinations. Tests, however, have established the presence of ample quantities of dissolved and gaseous hydrogen sulfide in this sewage and in its atmosphere.

Sulfide Studies

In 1941 the presence of hydrogen sulfide in sewage from different sources was investigated as a gauge of decomposition in relation to obnoxious odors. For the following 4 years various tests were made on the plant composite flow to measure the variation and extent of sulfide production. In addition individual sewers were checked to determine which of them were the main contributors to the sulfide picture. In most cases the sulfide content at the plant reached its maximum in September, going as high as 2 p.p.m. in sewage reaching the plant. Of the individual sewers, the bulk of the sulfide was found in the flow from meat packing plants. This went as high as 7 p.p.m.

In 1946 the emphasis was shifted from hydrogen sulfide as a gauge of odor production to hydrogen sulfide as a source of sulfur atmosphere in contact with concrete where it could be converted into sulfuric acid as a corrosive agent to deteriorate the concrete surface.

Tests showed that sewage from meat packing industries was a significant source of sulfide; also that to remove low concentrations (below 0.8 p.p.m.) of sulfide would require a chlorine dosage of 3 to 6 times the sulfide content. However, to reduce high sulfide concentrations to a little under 1 p.p.m., chlorine in the amount of twice the sulfide content would do the trick.

These relationships would form a basis for calculating whether chlorination might best be applied to sewage from an individual source or to the whole flow at a plant.

Required Repair Work

The concrete repair necessary at the G.W.S.D. plant was lengthy and costly. Gunite was used with Kalicrete cement. mortar. All disintegrated material was chipped off to sound concrete. In repairing to a depth of 4 in., a reinforcing mesh was used, secured to the concrete surface. Shallower depths were not reinforced.

There were 4,700 sq. ft. repaired in this fashion at a cost of about $2.92 per sq. ft.

Disintegration of Repaired Areas

Observations made during the first year after the surface gunite repairs were made indicated that the conditions which caused the disintegration of the concrete were still present but that no signs of sponginess or porosity were detectable. Later, however, it became apparent that a breakdown of the concrete surface was occurring.

In October, 1948 the plant chemist, O. Petursson, made a careful examination of the effluent discharge chamber and found that the walls and pillars were heavily coated with slime and fungus growths, especially for about 6 to 7 feet above the water line. At the water line and above it for a distance of 4 to 5 feet, there was considerable

evidence of sponginess of the concrete and the start of deterioration of the surface. This was especially noticeable along the bottom of the center curtain wall where a "skin" of concrete appeared to have been loosened from the wall.

Samples of this concrete "skin" were scraped from the walls and pillars at various points. All of the samples taken were heavy with sand due to the surface layer of concrete being so soft it was removed by the scraping tool.

The samples collected were washed with distilled water and the pH of the mixture determined. The pH values were as follows:

Sample 1—pH 2.90. Sample taken well above the water line, about 8 ft. below the ceiling. Walls damp, but not wet, and covered with a heavy layer of fungus and slime growth. Slime growth removed before sample was taken.

Sample 2—pH 5.45. Sample taken from well below water line along north wall and supporting pillars. Fairly heavy slime growth on surface but concrete was hard and smooth, showing no signs of sponginess or disintegration.

Sample 3—pH 3.30. Sample taken approximately at water line. Concrete appeared to be spongy and the top layer scraped off readily to about 1/16-in. depth. Very little slime growth noted.

From these observations it was apparent that free acid was working on the walls of the effluent discharge chamber at the points indicated and that conditions favorable to serious disintegration appeared to be present.

The gunite repairs made on the effluent discharge channel have not solved the corrosion problem caused by the effluent spray. The concrete disintegration experienced at Winnipeg leads to the conclusion that passages of effluent discharge chambers, and all other similar structures subject to the same conditions, should be designed so that streamline flow will occur and spray formation will be eliminated.

REPAIR OF CONCRETE DISINTEGRATED BY EFFLUENT SPRAY

By D. L. McLean

Superintendent, Greater Winnipeg Sanitary District

A peculiar case of concrete disintegration was experienced in the Greater Winnipeg Sanitary District's sewage treatment plant at Winnipeg, Manitoba, Canada. Spray from the plant effluent produced an acid attack on the concrete surface of the outfall chamber, so that over a period of 9 years as much as 3 in. of good, strong, alkali-resistant concrete was destroyed and the reinforcing steel was exposed (Figure 1).

Outfall Structure

The outfall chamber is approximately 50 ft. long by 25 ft. wide, and 20 ft. deep. It receives an average of 25 m.g.d. of effluent from two primary clarifiers, as well as raw sewage bypassed through the plant from time-to-time. The effluent falls 10 ft. from a weir and a sluice gate, with the production of considerable spray. The bypassed sewage is discharged under a 15-ft. head, which results in much turbulence and splashing.

Hydrogen Sulfide Action

During 9 months of the year hydrogen sulfide is present in the sewage in amounts up to 2 p.p.m. The concrete surfaces attacked were only those on which the spray fell. Where the spray did not fall, the concrete surface still

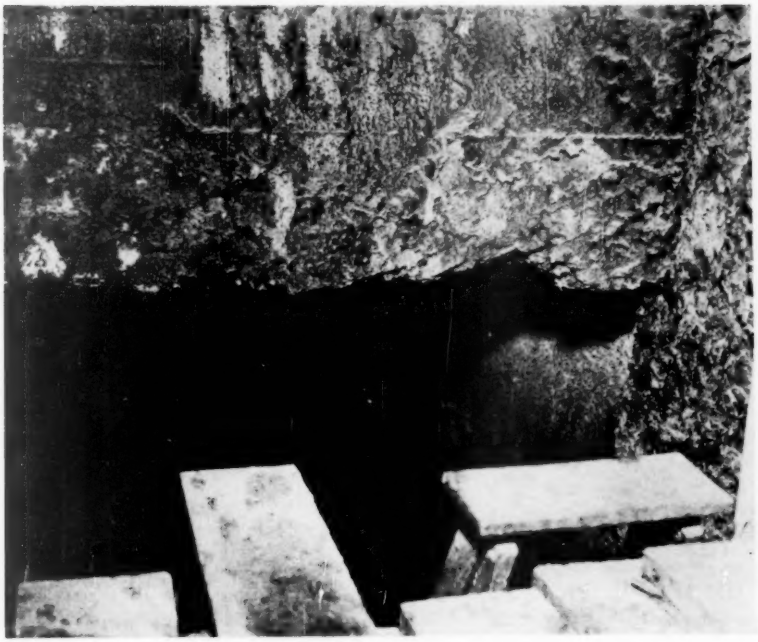


FIGURE 1.—Disintegrated concrete curtain wall at outfall chamber, Winnipeg sewage treatment plant.

shows the marks of the original form boards (Figure 2).

The original concrete was made from Kalicrete (alkali-resistant cement) and well-graded aggregate to give a 3,000 p.s.i. strength at 28 days. Where not attacked, the concrete was found to be very strong and hard to drill, but where the acid action had been at work the concrete had turned to a soft putty between the pieces of gravel. The concrete attacked had expanded, and the action was similar to alkali disintegration. However, Mr. Laidlaw, chemist for the district, showed that the putty-like concrete had a pH of 3.2 and that the disintegrating action was acid.

Method of Repair

In the fall of 1946 a gunite repair was made. First, all the disintegrated material was cut away and enough of the sound concrete was chipped off to insure a solid bond between it and the gunite mortar. No. 8 wire mesh, 3 in. by 3 in., held with 5-in. nails and ¼-in. cinch anchors was also used to help bond the gunite mortar to the original concrete. Figure 3 shows a column with the disintegrated concrete above. Below, the surface has been chipped, with the original reinforcing to be tied into the repair to help bond it.

The cement used for the repair was Kalicrete cement, and the aggregate was to the following specifications:

"All aggregate to pass a 3/8-in. × 3/4-in. mesh, set so that the longer dimension runs longitudinally, 12 to 25 % to be retained on No. 4 screen, the material passing the No. 4 screen to be well graded from coarse to fine with not more that 5% of it to pass the 100 mesh screen. The proportion of crushed stone is to be kept to a minimum."

The gunite surface was given a smooth, hard trowel finish before it set.

Figure 2 shows the column beams and walls restored by gunite. A portion of the roof where the spray does not hit shows the concrete unaffected and marks of the form boards still visible (December, 1946).

There were 4,700 sq. ft. of surface repaired, of which 4,100 sq. ft. was approximately 4 in. thick and was reinforced, and 600 sq. ft. was approximately 1½ in. thick and was not reinforced.

The itemized cost of the repair work is as follows:

Labor	$ 5,528.36
Rental of equipment	2,940.55
Board and traveling expenses	1,268.68
Materials:	
Cement, 640 sacks	640.00
Sand, 80 cu. yards	220.00
Reinforcing mesh and anchors	425.81
Lumber, nails, and sundry supplies	498.99
Temporary flume, including labor	528.11
Engineering fee	1,400.00
Miscellaneous	301.12
Total	$13,751.62

Test Patches

A special test patch of 1 : 2 Kalicrete mortar was put on a section of the outfall chamber wall in 1942 to see if the concrete there might have been below the high standard of the concrete used in the other structures of the District. This mortar patch was nearly all eaten away by 1946, and as there were only two isolated places on the 16 miles of intercepting sewers that showed similar action, there was no doubt that the special combination of spray and hydrogen sulfide was the cause of the acid attack. The two other spots referred to above were, first a patch of about 2 ft. square where the spray from the Mission sewer weir discharge gave similar action, and the second was an 18-ft. length of 24-in. concrete pipe where strong sulfuric acid had been in the sewer flow from time to time.

Protection Against Future Corrosion

The question arose as to how the repaired areas should be protected from future corrosion action. The spray in the outfall chamber could be eliminated by constructing costly conduits, by

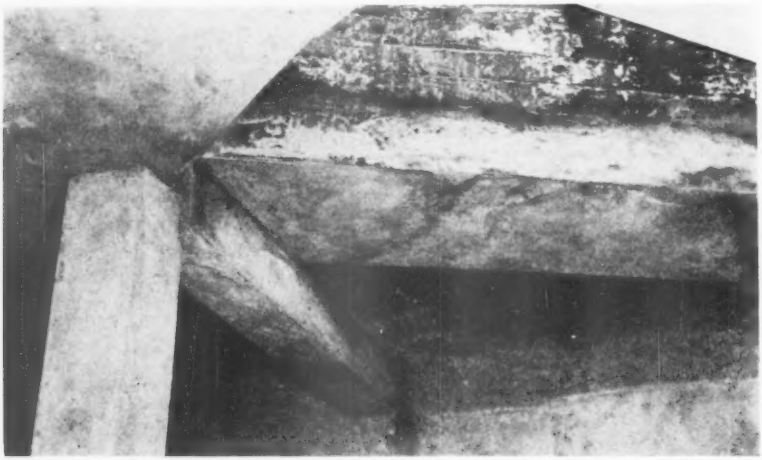


FIGURE 2.—Column, beams, and wall restored by gunite. A portion of the roof where the spray does not fall has the concrete intact with the original form board marks still visible.

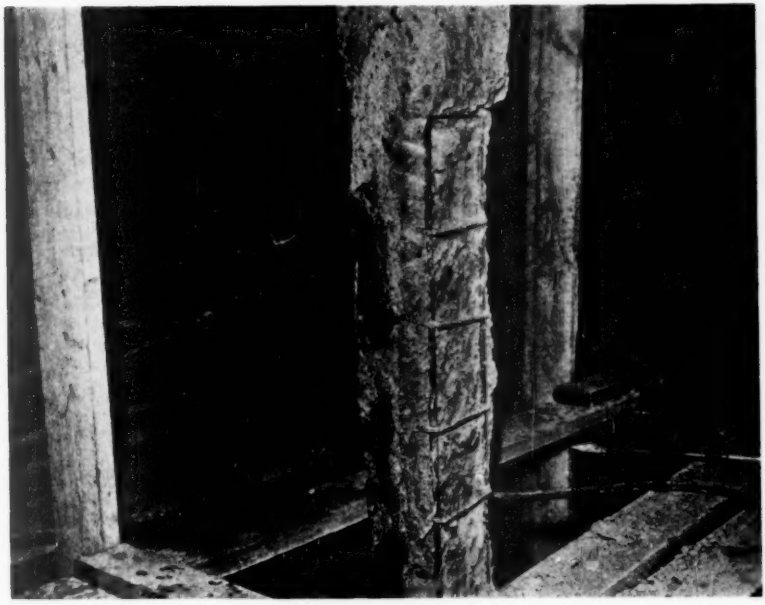


FIGURE 3.—Column showing disintegrated concrete above. Lower portion has been chipped to expose reinforcing which will be tied into the repair concrete for bond.

building a wooden spray chamber or lining, by chlorinating the effluent, or by providing a protective coating over the gunite surface.

Due to the denseness of the gunite mortar, it was thought that future corrosion action would be slow. After a year's observation, this conclusion appears sound as only $\frac{1}{64}$ to $\frac{1}{32}$ in. appears to have been affected. This is indicated by a sandy surface instead of the original hard troweled finish. Tests patches of various coverings have been put on the gunite repair and after a year's test, only "Heresite" paint remains in good condition.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"People who are not afraid to roll up their sleeves seldom lose their shirts."
—*Howard W. Newton*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Seventeenth Annual Report of the Aurora, Ill. Sanitary District Sewage Treatment Plant for the Year 1947 *

By Walter Sperry, *Superintendent*

On January 1, 1948, the District completed 85 months of complete dependance on plant power. There was no interruption of power during the year. Gasoline used as auxiliary fuel due to low gas supply amounted to 1292 gallons.

Plant Costs

The total administration and operating cost in 1947 increased from $40,164 to $47,335, or 17.8 per cent. One-half of this increase was due to the new and additional cost of carrying the Illinois Municipal Retirement Fund contributions. The remainder was due partly to new construction expense and partly to natural increases in material and wages.

Two additional features appear in the body of this report. One shows a comparison of the cost of supplies, wages paid, and total operating cost for the period 1938–47, divided into prewar, war, and postwar years. The other presents a flow diagram of the plant together with a brief historical sketch and a listing of the general equipment. This has not been included in any previous report.

* For last previous extracts see This Journal, **19**, 6, 1072 (Nov., 1947).

Fire Extinguishers

Completely overhauled and rebuilt the main entrance doors to the plant. These doors are oak veneer and receive the outside weather effects of a western exposure. While attractive in appearance they should never have been made of this particular wood since the veneering frequently comes loose and requires considerable maintenance.

In the fall of 1947 all of the fire protection apparatus, which consisted of a 40-gal. foamite tank, pyrene guns, and small acid-soda apparatus, was discarded in favor of six 20-lb. C-O-Two carbon dioxide tanks. These were carefully distributed about the plant as suggested by the insurance underwriter engineer and Mr. Ryan, Chief, Aurora Fire Department. Both of these gentlemen approved the change as being better adapted to the type of fire likely to occur about the plant. The carbon dioxide tanks are easy to recharge, unaffected by temperature, highly effective and instantly available. Furthermore, they do not deteriorate as does the pyrene and soda apparatus, and they require little attention except for an occasional weighting for loss of gas.

At the suggestion of the insurance

inspector, guards were placed over all exposed pump couplings.

Equipment Maintenance

The bar screen was improved by substituting steel brackets for the original cast iron brackets on the upper shaft, and the shear pin block was redesigned so as to employ two shear pins in balance. The shear pins were so designed that the shear section came in the middle so that either end could be inserted, at will, so long as the pin was made flush with the front of the shear block. This avoids misplacing the pin by inexperienced hands.

Split collars were applied on either side of the main eccentric plate of the Dorr sludge pump to correct side slip.

The Carter sludge pump was overhauled. A new air dome was placed on the discharge side, the switch mechanism repaired, and a compression band applied to the pump cylinder to repair a fine crack in the casting.

A gland packing problem on the main vertical shaft of No. 1 Digester remains unsolved. The 25-ft. 4-in. shaft of this digester is slightly sprung. This results in an eccentric section through the packing gland in the digester roof and, to date, all efforts to pack this gland have failed. The last effort was made by packing the gland with white oakum to which Carboseal was applied, which produces a 40 per cent swelling effect and is much used by gas companies for correcting leaks in gas lines. To date, this method has not worked.

Sludge Beds

During 1947 a total of 96,250 sq. ft. of sludge bed area were cleaned, equivalent to 1,078 cu. yd. at an average sludge thickness of 3.65 inches. The removal cost of $1,221.71 was equivalent to $1.13 per yard.

Heavy weed growths on some of the empty beds were taken care of by the use of the city park department's equipment whereby the weeds were sprayed under heavy pressure with arsenic solution.

Alum was applied to the sludge discharged to beds during the late fall and winter seasons.

A dipping needle was purchased to assist in a survey of manholes in the South Park sewer system. Most of these manholes are covered with gravel, which results from the fact that almost all the streets in this area are gravel and during the process of Township maintenance with graders the manhole covers are dragged off which lets in gravel and sand.

United Wallpaper Company Wastes

Late in 1947 the United Wallpaper Company began operation. As noted last year in this report, this is the largest wallpaper printing plant in the world and it will discharge an industrial waste consisting of 50,000 to 100,000 gal. of water per day which carries about 30 tons of clay per m.g., together with protein, casein, color bodies and alkalies, and in amounts that could discharge to the sewage plant upwards of 45 tons of clay per month. A part of the equipment of this plant consists of a chemical precipitation plant for the removal of clay. Studies in the District laboratory indicated that when the pH of this waste was reduced from 9.0 to 7.0, 40 grains of alum per gal. were required for good coagulation. Ferric and ferrous iron were found to be undesirable coagulants.

Quite by accident it was discovered that when the pH of the waste was adjusted to 5.0 with acids, the suspended solids would sharply coagulate, due to the presence of protein and casein. The explanation lies in the fact that the isoelectric point of the protein is at pH 4.8. Thus by the simple addition of acid the material will sharply coagulate but a corrosion problem is intro-

TABLE I.—Summary of 1947 Operation of the Aurora (Ill.) Sanitary District Sewage Treatment Plant

Item	Average
Rainfall (in.)	36.81
Tributary population (estimated)	56,000
Sewage treated (m.g.d.)	7.35
Screenings (cu. ft. per m.g.)	1.8
Grit (cu. ft. per m.g.)	2.9
Grease and scum (cu. ft. per m.g.)	0.64
Suspended solids (p.p.m.):	
Raw	193
Settled	80
Filter effluent	49
Final	28
Reduction (%)	85.3
Pounds per capita in raw	0.212
B.O.D. (p.p.m.):	
Raw	137
Settled	79
Filter effluent	35
Final	20
Reduction (%)	85.4
Pounds per capita in raw	0.150
Oxygen consumed (p.p.m.):	
Raw	50
Settled	41
Filter effluent	32
Final	20
Reduction (%)	48.0
Nitrogen as free NH_3 (p.p.m.):	
Raw	7.7
Settled	8.1
Filter effluent	1.5
Final	1.3
Nitrogen as total organic N (p.p.m.):	
Raw	19.6
Settled	15.9
Filter effluent	10.2
Final	8.5
Nitrogen as NO_3—final eff. (p.p.m.)	6.9
Raw sludge:	
Total solids (%)	4.7
Volatile solids (%)	73.3
Equiv. dry solids pumped (lb./day)	264.0
Final settling tank sludge:*	
Total solids (%)	5.2
Volatile solids (%)	60.2
Equiv. total dry solids pumped (lb./day)	25.0
Transfer sludge—1st stage to 2nd stage:	
Total solids (%)	2.0
Volatile solids (%)	57.3
Equiv. total dry solids pumped (lb./day)	117.0
Digested sludge:	
Total solids (%)	5.2
Volatile solids (%)	52.9
Supernatant (from 2nd stage digesters):	
Total solids (%)	0.44
Volatile solids (%)	51.3
Gas production:	
Cu. ft./lb. volatile matter added	7.80
Cu. ft./lb. volatile matter destroyed	12.30
Cu. ft./lb. dry solids	5.02
Cu. ft./m.g. sewage	5,960
Cu. ft. per capita	0.801
Gas produce in 1st stage (%)	74.2
Gas composition:	
CO_2 (% Vol.)	32.8
O_2 (% Vol.)	0.4
H_2 (% Vol.)	3.4
CH_4 (% Vol.)	62.9
H_2S (p.p.m.)	286
B.t u. (net)	577
Gas engine earning statement:	
Total engine investment ($)	18,321.50
Net earnings in 1947 ($)	4,002.87
Total net earnings—141 months ($)	58,019.39
Plant operating costs ($):	
Payroll	28,718
Retirement fund	3,170
Interceptor system	508
Truck	242
Office	579
Laboratory	189
New equipment	856
Repairs	1,807
Gas engines	1,964
Miscellaneous	2,705
Total	40,738
Total cost per m.g.	15.18
Total cost per capita	0.73
Total disbursements (operation, interest, bonds, etc.) ($):	
Per m.g.	45.69
Per capita	2.19

* To 2nd stage digesters.

duced. The District had specified that the suspended solids content of this waste should be reduced to below 100 p.p.m. before discharge to the District interceptor.

Gas Engine Repairs

In October, Engine No. 1 went through a serious failure due to fine cracks developing in the exhaust manifolds. Leaks also developed in the

heads around the inserts. This required servicing by a factory man and the replacing of two sections of exhaust manifold and three new cylinder heads.

At this time new Pierce governors were installed. The pump engines were originally equipped with Handy-Servo governors of the drum type. The drums had a cable passing to a float in the pump well so that as the water in the well rose and fell, the operation of the drum working on a screw controlled the speed of the engine so that the engine responded to high flows in much the same manner that a car is driven through the foot throttle. Through 10 years of operation, however, this governor ceased to be sufficiently sensitive. On the advice of the Climax Company the Handy-Servo governors were replaced with Pierce governors which eliminated the drum and substituted therefore a long lever, attached to the float cable, operating directly on the governor mechanism. The Climax Company stated that this type of governor was more generally used and well-liked because the direct action tended to be more sensitive.

Table I contains a summary of operation data for 1947.

Seventh Annual Report of the Gary (Ind.) Sanitary District Sewage Treatment Works for the Year 1947 *

By W. W. Mathews, *Superintendent*

Cost of Operation

Three items are considered in computing unit costs, viz.: sewage flow, contributing population, and 1,000 pounds of 5-day B.O.D. removed. The cost per capita is the most stable of these for this base changes gradually and in this case has been kept at a uniform figure over the period being considered. This total is probably too low and when an accurate census figure is available it will be possible to pro-rate the increase over the years and make corrections in this unit cost as required.

Cost Per Capita

Since the cost per capita is computed against a fixed base, any variation in total costs is reflected in this unit cost. This is apparent for the years 1946 and 1947. In 1946 cost of operating the Main Treatment Plant was $72,526.92 and in 1947 $84,981.01, with corresponding per capita costs of $0.7253 and $0.8498. This increase was made up of salary and wage adjustments; electric and utility gas used on account of excessive rainfall and runoff affecting gas production during the months of April, May, June and September; and supplies. Under supplies, one purchase accounted for $2,120.09 which included two exhaust boilers, one for a Cooper-Bessemer engine and one for a Worthington engine. The other miscellaneous supplies were routine maintenance purchases and the increase in cost was due mainly to rising prices. For example, a plunger for a raw sludge pump cost $26.00 in 1944 and $47.50 in 1947.

Problems of Operation

At Gary infiltration of fine sand into the sewer system causes excessive wear to take place on comminutor parts, raw sewage pump impellers, and on grit removal equipment. During 1946 slightly more than 60,350 cu. ft. of grit were removed while treating 7,437

* For last previous extract see This Journal, **19**, 3, 501 (May, 1947).

m.g. of sewage. This is at an average rate of 8.18 cu. ft. per m.g. Average rate for 1947 was 8.16 cu. ft. per m.g. Usually the amount of grit removed at sewage treatment plants ranges between 1.5 and 2.5 cu. ft. per m.g. At times the amount of grit removed at Gary exceeds 3.0 cu. yd. per m.g. Excessive wear results from handling this quantity of grit.

Pump No. 3 was operated more through 1947 than any other pumping unit, to determine if possible the life of the rubber covering on the impeller. At the end of the year operation hours totalled 5,734, and inspection on December 31st showed no apparent change in the coating for the preceding 3 months. The stainless steel leading edge of the impeller was bare while the remainder of the blades was still covered. Where originally there had been ⅛ in. of rubber covering on the leading edge, the rubber had tapered down to a feather edge. Visual inspection and feeling of the coating indicated that an almost static condition had been reached. While it was known that this was impossible, no apparent change could be noticed in the area still covered. No attempt was made to use calipers or micrometers in the inspection. Operation will be continued until erosion of rubber exposes a portion of the blades.

Treatment of Digester Overflow

At the Gary plant all overflow from the multi-digestion system flows back to the main sewer mixing with the raw sewage coming from the city. This method has worked very satisfactorily, even with the daily solids loading on the primary clarifiers ranging to as much as 3 times the average monthly loading and 6 times the annual average.

Suspended solids removed by the plant for the year totaled 21,314,261 lb. and is much higher than would ordinarily be expected with a connected population of 100,000. It is almost three times the 5-day B.O.D. removed. Suspended solids in raw sewage amounted to 21,678,530 lb. This quantity is computed from laboratory analyses of samples taken at the upper end of the grit chamber. The sewage at this point is a mixture of the sewage coming from the city of Gary plus the supernatant overflow from the multi-digestion system. Waste return sludge is not included; this is returned to the primary clarifiers after the grit chambers.

A total of 14,293,290 lb. of the above 21,678,530 lb. consists of solids in the supernatants or approximately 66 per cent of total shown in the summary. Deducting for supernatants leaves 7,385,240 lb. of suspended solids coming to the plant from the city. Therefore, in round figures the solids load from plant operation is twice that from the connected population and the solids instead of passing through the primary stage once are recirculated twice in addition.

About the middle of October the 5-day B.O.D. in the final effluent began to rise for no apparent reason. The flow was quite uniform, decreasing gradually each month to the end of the year on account of a dry period and resultant lowering of ground water level. It was thought that this B.O.D. increase might be caused by nitrification interfering with the B.O.D. determinations, and experiments are being carried on at present to discover the cause of the rise. Acidification and pasteurization is being used in the experiments, but not enough data have been obtained at the present writing to state any definite conclusions. The method of handling supernatant overflow from digesters has been detailed here, not that it has presented any operational problems but as an illustration of how plant operation may impose a heavy load on the treatment

TABLE II.—Summary of 1947 Operating Data, Gary (Ind.) Sewage Treatment Plant

Item	Average
Rainfall (in.):	
Recorded	39.50
Normal	33.17
Population served (estimated)	100,000
Equivalent population (0.17 lb. B.O.D./cap.)	153,100
Sewage flow:	
M.g.d.	19.86
Gal. per capita per day	199
Screenings removed (cu. ft. per m.g.)	0.06
Grit removed (cu. ft. per m.g.)	8.16
pH:	
Raw	7.0
Settled	7.1
Final	7.3
Suspended solids:	
Raw (lb. per cap. per day)	0.223
Raw (p.p.m.)	359
Settled (p.p.m.)	97
Final (p.p.m.)	6
Per cent reduction	98.3
B.O.D.:	
Raw (lb. per cap. per day)	0.223
Raw (p.p.m.)	157
Settled (p.p.m.)	71
Final (p.p.m.)	10
Per cent reduction	93.0
Activated sludge data:	
Aeration period (hr.)	4.95
Secondary settling period (hr.)	3.11
Secondary settling rate (gal./sq. ft./day)	701
Mixed liquor suspended solids (p.p.m.)	1,087
Sludge index	91.1
Returned sludge, suspended solids (p.p.m.)	3,918
B.O.D. loading (lb./1,000 cu. ft. aerator capacity)	16.3
B.O.D. removed (lb./1,000 cu. ft. aerator capacity)	13.8
B.O.D. removed (lb. per 1,000 cu. ft. air)	1.24
Returned sludge (% by volume)	40.4
Air consumption:	
Million cu. ft. per day	8.5
Cu. ft. per gal. sewage	0.46
Cu. ft. per lb. B.O.D. removed	808
D.O. at end of aeration (p.p.m.)	6.4
Blower pressure (p.s.i.)	8.22
Raw sludge:*	
Average daily pumped (gal.)	162,171
Per cent dry solids (ave.):	
Total	4.6
Volatile	52.0
Digested sludge:	
Ave. total solids (%)	6.76
Ave. volatile solids (%)	54.75
To drying beds (tons of 50% moisture)	4,479
Gas production:	
Cu. ft. per cap. per day	1.61
Cu. ft. per m.g. sewage	8,128
Cu. ft. per lb. solids added	2.7
Cu. ft. per lb. volatile solids added	5.2
Value of gas used ($)	24,063
Gas analysis:	
CO_2 (%)	28.7
CH_4 (%)	66.5
Hydrogen (%)	3.8
Nitrogen (%)	0.9
H_2S raw* (grains per 100 cu. ft. gas)	4.17
H_2S scrubbed (grains per 100 cu. ft. gas)	3.17
Heat value (B.t.u.):	
Net	664
Gross	732
Bacterial analysis:	
Raw sewage (total bacteria per ml.)	543,000
Final effluent (total bacteria per ml.)	53,800
Raw sewage (B. coli M.P.N. per 100 ml.)	2,400,000
Final effluent (B. coli M.P.N. per 100 ml.)	96,000
Outlet stream analyses (p.p.m.):	
Upstream ¼ mile:	
D.O.	3.59
B.O.D.	2.77
Downstream 2¼ miles:	
D.O.	3.83
B.O.D.	3.58
Treatment costs ($):	
Per m.g.	11.72
Per capita per year	0.85
Per 1,000 lb. B.O.D. removed	9.61

* Includes waste activated sludge solids and solids in secondary digester supernatant liquor.

process. Also the data from this method will be available and of value when at some future time design of plant additions are required.

Gas Production

The return of solids to the intercepter and to primary clarifiers has demonstrated that this has an effect on

gas production. The large amount of partially digested solids returned to the clarifiers seeds the raw sludge so that there is evidence of some digestion taking place in the clarifiers. The exception to the above is when washouts have occurred during time of storms when pumpage through the primary stage is at approximately 60 m.g.d. rate for clarifiers designed to treat 40 m.g.d. Sludge depths at side walls at times reach 18 in. No attempt is made to keep clarifiers pumped clean, rather some sludge is stored in the clarifiers at all times.

When the seeded raw sludge is pumped to the digesters in rates in excess of that normally used, an increase in the rate of gas production will be noted within less than 24 hours. Furthermore if digesters are drained so that very small amounts of solids are returned to the intercepter for several days, an appreciable falling off in the rate of gas production will be noticed. As a result of this experience a draining schedule has been instituted which consists of draining a small amount each day if possible. This is done to keep the overflow as uniform as possible with fairly uniform gas production. All routine operation is out, however, during storms, which, if severe, create the problem of getting rid of the surplus runoff.

Aerator Loading

With septic action taking place in the primary clarifiers, loading on the aerators is probably increased slightly. This has never been enough at Gary to interfere with the treatment process since the solids content of the final effluent is uniformly low, averaging 6 p.p.m. for 1947. With air applied at an annual rate of 0.46 cu. ft. per gal., the D.O. at the end of aeration averaged 6.4 p.p.m. While the D.O. at the end of aeration is somewhat above the accepted operational minimum, in this case experience indicates that to have a vigorous spiral flow, about 0.45 cu. ft. of air is required with five aerators in service. Except when the plant was first placed in operation, neither of the gas-driven blowers has been operated at full speed, which is 400 r.p.m. Average operating speed is about 90 per cent of full speed with one blower in service.

Operating data for the plant for 1947 are summarized in Table II.

Fourteenth Annual Report of the Galesburg (Ill.) Sanitary District Sewage Treatment Plant (1947) *

By L. W. Hunt, *Superintendent*

The need for additional secondary treatment remains quite urgent. Since sewage pumping costs have been materially reduced by the installation of gas engine-driven pumps, a much greater portion of the storm flow has been given treatment. When flows are in excess of approximately 5.5 m.g.d. rate the filter nozzles spray continuously at low head. When this condition exists the distribution of sewage over the area of the bed is very unsatisfactory. There is also evidence that the top stone is too fine, which aggravates the "ponding" problem. In regard to the organic load on the filter, it is interesting to note that it is approximately four times that of the Aurora, Ill., treatment plant. In February 1946, the top filter stone was picked, and in April, 1000 lb. of chlorine was applied to the filter influent to

* For previous extracts see This Journal, **15**, 6, 1208 (Nov., 1943); **9**, 2, 297 (Mar., 1937).

relieve "ponding." In 1947 the stone was picked in January and April.

Gas Engine Costs

The economy of using the sewage sludge gas for operating the sewage pumps is shown by the fact that the net saving in power costs (exclusive of investment charges) for 1946 and 1947 was $3,100 and $2,690, respectively. The first engine was installed September 1940. On January 1, 1948, it had been in service a total of 54,070 hours, which represents 85 per cent of the total time. The average annual maintenance cost has been $356. The total saving (exclusive of investment charges) over all-electric pumping has been slightly over $19,000, or a yearly average of $2,700. With the installation of the second engine in March, 1947, it is not necessary to operate the electrically driven unit while engine maintenance work is being done. Over the 2-year period 57 per cent of the total gas production was utilized by the engines.

The installed cost of the new six-cylinder gas engine that replaced the 60 h.p. electric motor on No. 2 sewage pump was as follows:

Contract price of engine	$4,450.00
Materials	1,628.09
Labor	830.09
Total	$6,908.18

Installation was accomplished by district employees. In 1940 the installed cost of the first gas engine was $5101.16.

Gas Explosion

On May 29th, 1947, the building which houses the machinery for Di-

TABLE III.—Summary of Operation Data for 1947 at Galesburg, Illinois

Item	Average
Connected population	30,000
Equivalent population (B.O.D.)	39,600
Rainfall (in.)	38.30
Interceptor flow (m.g.d.)	6.50
Sewage receiving primary treatment (m.g.d.)	5.05
Sewage receiving secondary treatment (m.g.d.)	4.80
Screenings (cu. ft. per m.g.)	0.49
Grit removed (cu. ft. per m.g.)	3.20
pH raw sewage	7.5
pH final effluent	7.5
Suspended solids:	
Raw (p.p.m.)	186
Settled (p.p.m.)	84
Filtered (p.p.m.)	73
Final (p.p.m.)	52
Reduction (%)	71.4
Raw (lb./cap./day)	0.246
B.O.D.:	
Raw (p.p.m.)	161
Settled (p.p.m.)	110
Filtered (p.p.m.)	54
Final (p.p.m.)	44
Reduction (%)	70.6
Raw (lb./cap./day)	0.212
Filter loading:	
Pounds B.O.D./acre ft.	635
Pounds B.O.D./1,000 cu. ft. media	13.3
Pounds B.O.D./cu. yd. media	0.36
Primary sludge:	
Total solids (%)	7.7
Volatile solids (%)	62.3
Secondary sludge:	
Total solids (%)	1.6
Volatile solids (%)	56.1
Digested sludge:	
Total solids (%)	7.8
Volatile solids (%)	45.1
Gas production:	
Cu. ft. per lb. T.S. to digester	5.11
Cu. ft. per lb. V.S. to digester	8.32
Cu. ft. per cap. per day	0.87
Cu. ft. per m.g. raw sewage	5,517
Operating costs ($ per m.g.):	
Gas engines	0.36
Payroll	13.50
Power	0.87
Trucks	0.40
Laboratory supplies	0.03
New tools and equipment	0.11
Repairs	0.34
Office expense	0.07
Insurance	0.70
Care of grounds	0.32
Miscellaneous	0.47
Total	17.17

gester No. 3 was damaged by an explosion of sewage sludge gas. A heavy rain and windstorm occurred during the night, which resulted in power failure from 10:20 P.M. to 4:30 A.M. After power service was restored all motors had been started and the plant was in normal operation.

About 5 A.M. operator Henry Hanson, in the course of his routine work, opened the door of this building and as he turned on the light an explosion occurred. Mr. Hanson received burns on his face, hands, and back which necessitated him being off the job until August 1st. The south and west walls of the building were pushed outward several inches at the ceiling.

Plant operating data for 1947 are summarized in Table III.

COST TRENDS VERSUS BUDGET INCREASES

By Walter A. Sperry

Superintendent, The Aurora Sanitary District, Aurora, Ill.

Recently a bread distributor, a printer, an automobile mechanic, and a utility maintenance superintendent were playing bridge. During their conversation it developed that none of these men made less than $97 per week. This is an interesting commentary on the subject of these notes and contains much of the explanation for the alarming rise in budget requirements of sewage treatment plants.

Aurora Cost Study

This experience led to a review of the plant operating cost data of the Aurora, Ill. Sanitary District. A study was made of the records from and including the year 1938 through 1947. The years 1938 and 1939 were prewar years, 1940 through 1945 were war years, and the years 1946 and 1947 represented the postwar period.

The cost per million gallons, cost per capita per year, estimated connected population, and million gallons sewage treated for this period are set forth in the following table. These costs represent operating costs and do not include administrative costs.

Year	Population	M.g. Treated per Year	Cost per M.g. ($)	Cost per Capita per Year ($)
1938	49,000	2640	9.23	49.71
1939	49,000	2540	9.95	51.70
1940	49,000	2470	9.64	48.60
1941	49,000	3070	8.60	53.91
1942	49,000	2820	10.46	60.27
1943	51,000	2850	9.17	51.27
1944	51,000	2420	11.63	55.25
1945	51,000	2450	12.02	57.83
1946	54,000	2270	14.69	61.65
1947	56,000	2680	15.18	72.75

It will be noted that the cost per million gallons increased 53.6 per cent and the cost per capita 46.0 per cent for an increase in population of 14.3 per cent during this period. It will be further noted that the total flow treated by the plant averaged 2,621 m.g. per year, which was a variation of but 13.5 per cent above the minimum year of 1946 and a similar per cent below the maximum year of 1941.

Salary Increases

Salaries constitute approximately 77 per cent of the total operating cost. A study of the time books gives the following tabulation of wages paid in

dollars per month to plant employees on January 1st of each year.

	1938	39	40	41	42	43	44	45	46	47	48
Clerk and Lab. Asst.	150	150	150	167	175	185	233	275	275	300	340
Chief Operator	125	125	150	150	175	185	180	200	220	245	270
Day Operator	125	125	125	125	137	147	146	156	156	177	208
Night Operator	125	125	125	125	137	147	224	224	187	208	230
General Labor	94	94	94	104	123	139	145	166	177	175	208

The above table shows an increase of 127 per cent paid for laboratory and clerical assistance (one person), 115 per cent for the chief operator, 67 per cent for a day operator, 84 per cent for the night operator and 124 per cent for general labor. In 1944 the clerk and laboratory assistant assumed the bookkeeping for the District at an increase in wage. In November 1945 the night operators' work period was changed from 12 to 8 hours. In general, the table is based on a 48-hour week. Labor that cost 40 to 45 cents per hour in 1938 now costs $1.10 per hour. A sweeper in a local plant now earns $1.265 per hour.

Supply Costs

A review of many of the routine supplies required for plant operation reveals further interesting increases in costs as shown by the following tabulation:

Readers outside metropolitan areas should remember that the smaller communities near large cities, like Chicago, undoubtedly pay more for both wages and general supplies than elsewhere. The table above gives a representative study of routine items in constant demand and shows a general upward cost increase of from 31.2 to 178 per cent.

All three of the tables given show that unusual price increases did not begin until the year 1943. Since that time prices have sharply increased. Requisitions can seldom be written priced in advance since acknowledgments are now marked with the familiar current phrase "prices subject to delivery date." In fact, prices are changing so fast that formal contracts are almost nonexistent since the lag in time between contract signing and the start of the work completely upsets the cost estimates.

With these detailed studies as a base, a review of the plant operating

Item	Cost ($)			Per Cent Increase
	1938	1943	1948	
Gasoline, per gal.	0.188	0.195	0.262	39.4
Magnetos	38.00	45.00	67.00	76.5
Valve seats	0.80	0.87	1.22	52.5
Cylinder blocks	68.00	78.20	120.75 ('47)	76.5
Motor oil (bbl. lots) per gal.	0.495	0.54	0.65	31.2
Shop engine labor, per hour	1.25	2.25	3.00	140.0
Nails	0.05	0.06	0.10	100.0
Mops	0.60	—	1.24	106.0
Paper, per ream	0.98	1.18	2.25	130.0
Sludge pump ball valves	7.25	9.13	9.70 ('46)	33.8
Sand, per ton	0.50	0.55	0.90	80.0
Power mower sharpening	4.00	6.00	8.50	113.0
Wiping rags, per lb.	0.11	0.15	0.225	104.0
2×4's, No. 2 W. Pine, per 1000 bd. ft.	54.00	87.50	150.00	178.0

costs between 1938 and 1947 gives the following interesting comparison:

Period	Years	Costs ($)
Wages paid:		
Prewar	1938–39	18,666
War	1940–45	21,668 (16.1% more than 1938–39)
Postwar	1946–47	27,531 (27.0% more than 1940–45; 47.5% more than 1938–39)
Supplies:		
Prewar	1938–39	745
War	1940–45	1,768 (137.0% more than 1938–39)
Postwar	1946–47	2,093 (18.0% more than 1940–45; 181.0% more than 1938–39)
Total operating costs:		
Prewar	1938–39	24,840
War	1940–45	27,230 (9.6% more than 1938–39)
Postwar	1946–47	35,430 (30.0% more than 1940–45; 42.8% more than 1946–47)

Plant operating costs at Aurora would have been much greater after 1940 if gas engine-driven generators had not been installed at that time which eliminated all payments to the local power company for lights and auxiliary motor power.

Current prices do not as yet indicate that the upward climb of sewage treatment works costs has reached its peak. It undoubtedly will be some time before this occurs.

USE OF CLOROBEN FOR ODOR CONTROL

By John K. Frei

City Sanitary Engineer, Springfield, Mo.

Odor control at the Springfield, Mo., Southwest sewage treatment plant was accomplished for several years by the use of ferric and ferrous chloride manufactured by the Scott-Darcy process. The Southwest plant is a modified trickling filter plant of modern design. The plant has been operating at maximum capacity, handling a sewage flow of approximately 11 m.g.d., contributed by about 75,000 population together with milk and meat processing plants.

Treatment Plant Units

The treatment units composing the Southwest plant are as follows:

Raw sewage pumping station
Mechanically cleaned grit chamber
Mechanically cleaned bar screens
Reaction tank and chlorinators for the production of ferric and ferrous chloride by the Scott-Darcy process
Preaeration tanks for grease removal
Primary settling tanks—P.F.T. Multiple Tray Clarifiers
Roughing filters
Secondary settling tank
Final filters
Final settling tank
Digesters
Sludge drying beds

Application of Cloroben

Cloroben was tried as an odor control substitute for chlorine because ton chlorine containers were not available and the cost of using 150-lb. cylinders of chlorine was prohibitive. Since funds for chemicals were budgeted and a number of 150-lb. cylinders of chlorine had been purchased, the experi-

mental use of Cloroben was rather limited in scope.

Cloroben was first applied for a period of 15 days, from June 27 to July 10, 1947. The high-speed roughing filters were given shock doses of approximately 3 p.p.m., over a period of 12 hours, on June 27 and 28. The filter beds also were given a shock dose of 3 p.p.m. on June 28 and 29. Grit chambers, channels, and screens were sprayed with a 10 per cent solution of Cloroben, as was the grit before it was hauled to the burial ground. As much of the grit burial grounds as could be reached with the equipment was sprayed with a 20 per cent solution.

Treatment of raw sewage with Cloroben was started June 28, using approximately 1 p.p.m. continuous feed with a sewage flow of 8 to 10 m.g.d. A second test was made from August 14 to September 17, with 1 p.p.m being added continuously to the raw sewage. No shock doses were applied during this period, but the channels, screens, and grit chambers were sprayed with a 10 per cent solution. The grit burial ground was not sprayed during the second test period.

An explanation of the grit problem at the Southwest plant is necessary in order to understand conditions there. A tremendous number of snails slough from the filter units during the summer and are removed from the system through the grit chamber. From 20 to 40 cu. ft. of these snails are taken from the grit chamber each day. Prompt burial of this material is required since it becomes odorous in a very short time.

Cloroben was fed to the raw sewage by using a 55-gal. steel barrel with a pet cock placed at the bottom. The barrel was set over the junction manhole of the incoming plant sewers, which is located about 50 ft. from the pump station, and the Cloroben solution applied at the desired rate. At the rate used, it was necessary to refill the barrel about every 6 hours.

Results

During the test periods the sewage odor was completely eliminated in the powerhouse where the bar screening equipment is located. The only odor detectable was a slight smell of Cloroben.

The heavy grease crusts on tank and channel edges and on equipment were softened during the period of Cloroben application and at many places they completely disappeared. It is probable that if additional spraying of structures had been done all grease formations could have been removed.

The plant operators were all of the opinion that the raw sludge pumping units operated much better and with less clogging during the time Cloroben was used. The number of nozzles on the 6 filter distributors requiring daily cleaning was reduced over 50 per cent during the treatment period, and for a few days thereafter. The odor from the plant, which comes primarily from the trickling filters and sludge drying beds, did not increase or decrease while Cloroben was being used. There was, however, a faint Cloroben odor detectable which helped to mask the odor from the filters. No noticeable reduction in the number of filter flies was observed during the treatment period.

Odors from the grit burial grounds were effectively controlled by the spraying of Cloroben, and where the spray fell on weeds these soon curled and died.

Summary

The conclusion drawn from the limited use of Cloroben at the Southwest plant during the summer of 1947 is that Cloroben can be used effectively to control odors in sewage and around the treatment plant. Based on the 1947 experience, plans have been made to use approximately 1,500 gal. of Cloroben for odor control during the spring and summer of 1948.

TIPS AND QUIPS

Supernatant Liquor Problem Licked

When H. C. Parker, superintendent of the Riverside, Calif., sewage treatment works, experienced digester trouble caused by the discharge of excessive quantities of oil to the sewers, it wasn't long before he found he had a clarifier problem on his hands also. The upset condition of the digesters soon produced a supernatant liquor that couldn't be settled satisfactorily in the primary clarifiers.

Although Parker's problem was by no means unique—quite contrary in fact, as many gray-haired operators can testify—his solution of the supernatant liquor disposal problem was one which has been tried by only a handful of plant operators, and reported by even a smaller number.

In spite of the fact that the standard rate trickling filters were badly ponded as a result of a large volume of oil which had carried over from the settling tanks, Parker decided to bypass the clarifiers and put the supernatant liquor, containing over 16,000 p.p.m. of suspended solids, directly on the filters. Such a decision must have taken considerable courage!

One immediate result was to reduce materially the settled sewage load on the filters, the B.O.D. of the settled sewage dropping from 136 to 82 p.p.m. Contrary to current belief as to what should have happened, when the supernatant liquor was discharged to the filter, the filter ponding not only did not increase but actually began to clear up and soon the filters were in excellent condition.

In relating his experience at the June, 1948, meeting of the California Sewage Works Association, Parker reported:

> "At the present time no ill effects have developed due to the application of digester supernatant to the filters. The filters have a blue-green apearance and ponding is a thing of the past."

Since January 1, 1948 (to April 30, 1948) the Riverside plant has been receiving an average raw sewage flow of 3.2 m.g.d., having a B.O.D. and suspended solids content of 292 p.p.m. and 293 p.p.m, respectively. Plant effluent B.O.D. and suspended solids have averaged 14 p.p.m and 16 p.p.m., during which time the filter loading has been 0.356 lb. per cu. yd. of filter media, or 634 lb. per acre foot.

There are strong indications that, within limits, trickling filters may prove to be as effective as activated sludge units for disposing of supernatant liquor.

What's in a Name?

It is seldom any sewage works operator has such a perfect alibi to offset the possibility of filter fly troubles as has D.H.A. Price, manager of the sewage purification works, Rochdale, England.

Commenting on the lack of a filter fly problem at his plant, Mr. Price makes this tongue-in-cheek reflection:

> "It is significant that the names of two adjacent riverside places, Midgehall and Gnat Bank, are older than the sewage works."

It must be nice, even in a trouble-free present, to have that money-in-the-bank feeling!

A Tip-of-the-Hat to Michigan

A well-deserved tip-of-the hat goes to the Educational Committee of the Michigan Sewage Works Association for its efforts on behalf of the Michigan operators. Realizing that most operators need and desire more training in their work, the committee organized and held a Sewage Works Operators' Short Course at Michigan State College in 1947. The course was designed to cover a 4-week period with subject matter arranged so that operators could take one or more weeks of study each

year or complete all 4 weeks during a single session. Total attendance during the course was 36. The short course is to be offered each year.

In 1948 the Committee cooperated with the University of Michigan Extension Service in presenting an extension course on Industrial Wastes Disposal. The course was held in Detroit and consisted of twelve 2-hour lectures. Following completion of the course, a questionnaire was sent to the 131 enrolled students. The returned answers indicated that the material presented was well received.

Plans of the committee for 1949 include continuation of the Operators' Short Course, presentation of a high-level in-service training course on Stream Sanitation, additional extension courses on chemistry and hydraulics, and development of correspondence courses in cooperation with the University of Michigan Extension Service.

The important aspect of the committee's accomplishments which should be noted is this: leadership and initiative for all of these educational activities have come directly from the Committee which has taken seriously its responsibility for providing educational opportunities for the MSWA members.

All Member Associations could use to advantage Educational Committees as energetic and effective as the one now serving the Michigan Association.

Filter Icing Reduced by Filter Center-Well Cover

An effective method for reducing ice formation on trickling filters was discussed at the Spring Meeting of the New York State Sewage Works Association last June by George H. Bush, Superintendent, Brighton Sewer Commission, Brighton, N. Y. The filter at Mr. Bush's plant is a conventionally designed trickling filter of 50 ft. diameter, having an uncovered center well for ventilation and inspection. Sewage is applied to the filter by means of a 4-arm rotary distributor.

Mr. Bush described the filter icing problem encountered and its solution as follows:

"The first winter the sewage plant was operated, when the temperature went down to 10° F. ice began to build up on the filter surface and soon became so extensive the filter would not operate. The problem was solved by placing planks across the filter center well. Less than 6 hours after the planks were placed the ice had melted sufficiently to permit normal operation of filter.

"The planks did the job very well but they were a constant hazard and nuisance. They were very slippery and the operators could never be sure just how strong they were. An added disadvantage was their continuous replacement expense.

"To take the place of these planks we installed a metal cover for the filter center well. This cover is attached to the distributor and rotates with it. One of the plant operators constructed the cover, and while it is not as finished a job as is desired, it serves its purpose very adequately.

"The metal cover has a hinged door whereby a man can enter the center well to grease the distributor rollers and operate the distributor bypass and drain valve.

"Ice formation on the wall at the outside of the filter was eliminated by tapping the end gates of the distributor arms and installing a spray nozzle so that sewage was sprayed on the inside of the wall. This spray was also found to be useful in the summer when DDT was applied to the settled sewage for filter fly control.

"Since the center well cover and distributor arm sprays were installed it has been possible to leave the filter operating continuously during the winter months."

Mr. Bush's idea could be advantageously adopted by many operators who are now using various types of wooden covers for filter center wells. The covering of exposed dosing tanks during cold weather also will materially aid in controlling ice accumulation on trickling filters.

A metal cover on the dosing tank and filter center well is certainly better than a blanket of ice on the filter!

Florida Sewage Works Association Scores News Beat!

Honors for the first published report of the 21st Annual Meeting at Detroit last October go to the Florida Sewage Works Association's news letter *News and Notes*. As a matter of record, *News and Notes* didn't even have any competition.

Six days following the close of the Detroit meeting, *News and Notes* appeared at Federation headquarters carrying a front page picture of the convention hotel and Detroit's skyline as well as a summary of the Federation meeting. Florida Association members must have received this convention news not later than 4 days after the convention ended, which is somewhat of a record.

THE CORNER strongly suspects the energetic editor of *News and Notes*, Perry Teeple of Jacksonville, with having engineered this scoop, and herewith extends its congratulations. This speedy news-reporting service the Florida Association is receiving is only one of many indications of the energy and resourcefulness of its officers and members.

The boys down Florida-way are planning big things for the 1952 Federation meeting. And at the rate they're going they'll certainly deliver!

Freeing Frozen Lubricated Plug Valves

The question of the best type of valve for use at sewage works is always good for a discussion among sewage works operators. The gate-valve men claim plug valves lead only to strained backs or valves that can't be closed, while the plug-valve boys point to the wheel blisters on the hands of gate-valve operators and glibly recite accounts of shearing off 4 x 4's that have been encountered in sludge lines. All are agreed, however, that all valves, regardless of type, require intelligent maintenance.

Lester Pope, operator of the Hamilton Township, N. J., sewage treatment plant, is one of many sewage works operators who have learned about plug valve maintenance the hard way. What he learned on freeing such valves when they are stuck is a valuable bit of information well worth passing along and remembering. The story, as Pope told it at the New Jersey Sewage Works Association meeting last March, is this:

"When plants are designed and built the different equipment companies send along with the equipment instruction books, prints, and special tools. The contractors install the machinery and then promptly lose the tools, prints, and instructions.

"This is exactly what happened at our plant, which is a 4.5 m.g.d. complete treatment plant with separate sludge digestion and chlorination. The first trouble that developed was with the lubricated plug valves.

"Instruction books for plug valves, regardless of make, describe and illustrate how such valves should be serviced to keep them in good operating condition. The instructions are adequate too, if followed. But suppose nothing is done until a valve sticks. What then?

"That is what happened to me with eight 6-in. digester draw-off valves. These valves were stuck so tightly that it took a 6-ft. leverage to start some and some could not be moved at all.

"I tried everything I knew and finally asked for help from the manufacturer, who was only too glad to give assistance. Two manufacturer's representatives arrived at the plant in short order, ready to work.

"I had a small Lincoln pressure grease gun that bolts onto the top of a 50-lb. pail of grease. We used this gun, cleaned out the grease, and in place of the grease hose used a small length of 1/8-in. pipe. The gun and pipe was connected directly to the grease port of the plug valve.

"With the gun supplying the pressure, 'drip oil' obtained from the local gas works was pumped directly into the valve. At first it appeared that the gun would not do the job, but shortly the 'drip oil' started to

go, and in a very short time we were able to move the plug valve with the regular wrench.

"We worked each valve back and forth, pumping in 'drip oil' until we were sure the valve was free. Then we greased them and returned the lines to service. Today these valves work perfectly and no further trouble with them has been experienced. However, they have been greased regularly since they were fixed.

"This experience with 'drip oil' has since proven very helpful because now anything that won't work gets a shot of 'drip oil' first."

Death Is So Permanent

Is there any group of men as careless with their lives as sewage works men? Any other vocation where death is so lightly treated and the basic elements of self preservation so frequently flouted? One wonders, sometimes, after noting the sewage works accidents that are reported month after month.

Reports of two recent sewage works accidents are typical of what occurs with appalling regularity. One report concerns the death of a father and the near death of a son in a sewer manhole at Muskegan Township, Michigan. It's the old story of entering an improperly ventilated manhole without testing for toxic gases or oxygen deficiency.

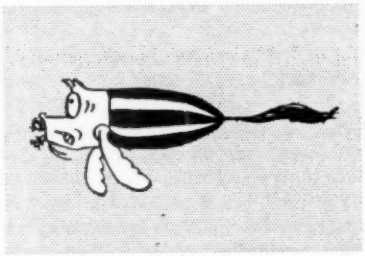
The other report is that of a sewage works operator in Iowa who was almost fatally burned—third degree burns on 40 per cent of the skin area—because he forgot that gasoline vapors and an open flame are a deadly team. While at work in the sewage works service building, cleaning jars with gasoline, a flashback from the digester heating boiler completely enveloped in flame this unfortunate but careless Iowa operator.

Perhaps every sewage works operator should be required to read the Federation's Manual of Practice No. 1 at least once a week, particularly Appendix A in which are listed a few of the occasions when sewage works men have been killed or injured because of careless working practices.

Take time to work safely. "THE LIFE YOU SAVE MAY BE YOUR OWN!"

Picture of a "Pollute" *

Pictured here is a Pollute, one of the minute but deadly li'l creatures which cause water pollution and kill every living and some of the dead things in streams of Florida. A picture of a Pollute was not contained in Jim Massey's book on Florida stream pollution now available at the JOURNAL because up to press time we couldn't catch one of the dirty little rascals.



Pollutes are so small that the number of 'em required to fill a jigger contains so many digits it looks like a Washington appropriation for a bureau in the "Pension-Gone" building in Washington without a $ mark.

If you want to see what Pollutes can do to a stream besides kill everything in it, take a boat ride up Rice Creek.

That'll give you an idea.

* By Bill Pinney, *The Jacksonville (Fla.) Journal.*

Editorial

FEDERATION SUPPLEMENTS INDUSTRIAL ORGANIZATIONS

The paper presented elsewhere in this issue under the title "Stream Pollution Control Activities of Industrial Associations" describes a gratifying upsurge in the industry-wide attack upon waste control problems, through unified and channeled efforts by various industry service organizations. This movement, if accentuated in the programs of all associations serving "wet-waste" industries, presages a significant advance in stream sanitation.

The Federation of Sewage Works Associations occupies a front-rank position among the proponents of clean streams who are encouraging trade association activity. United surveys, studies and research in each industry are infinitely more efficient and productive than are similar efforts in the individual factory or mill, the findings from which are usually retained in seclusion. The reluctance within each industry to exchange information has heretofore been the greatest obstacle to real progress.

Acceptance of the waste control problem as an obligation of industrial service groups does not in any way relieve the Federation of responsibility. In fact, the opportunities for Federation service are enhanced. It is our purpose here to outline the over-all pattern of interest, and to point out the key position that is held by the Federation.

The interests of the industry association are "vertical" in direction; that is, they are confined to the stream pollution or any other problem only so far as the particular industry (meat packing, steel, dairy, paper manufacture, etc.) is affected. The membership of the industry association is restricted to those engaged in the various operations associated with the specific industry. It represents the "know how" and the "know who" within its industry, but not outside.

There is a need, then, for an organization which aims to advance fundamental knowledge concerning the nature, collection, treatment and disposal of *all* wastes that may cause stream pollution, regardless of origin. The Federation is such a "horizontal" organization, equipped to gather the information that is available and to dispense it wherever needed. It is true that a major share of the Federation's interest is devoted to municipal sewage collection, treatment and disposal, but this is one of the chief advantages that it offers to industry. The manufacturing or processing plant that can get rid of its wastes by discharge to the public sewers is indeed fortunate, and it is very much to industry's advantage for the science of municipal waste treatment to be advanced to the greatest possible extent.

But the most important feature of the Federation is its common attraction to every individual or agency that is interested in preventing or abating stream pollution. It is a neutral meeting ground for representatives of all industries with governmental pollution control agencies, municipal authorities, research experts and the technical specialists who design and operate waste treatment and disposal works. The engineer, chemist, biologist and the administrator gathers here to integrate his professional abilities

and skills into a single objective. Divergent points of view may be given expression, to the end of universal understanding among those who produce wastes, those who establish stream standards, and the technologists who must meet the requirements of all interests. Through its state and regional constituent units, the Federation carries these same benefits into localized areas.

No individual industrial association or other professional society affords the basic approach to stream pollution control that is provided by the Federation. However, the valuable work of these unrelated "vertical" groups can be guided and coordinated through the medium of the "horizontal" organization. The Federation welcomes the opportunity to supplement and broaden these efforts. The manner in which it is doing so has been reported in an earlier editorial (THIS JOURNAL, **18**, 6, 1217; November, 1946).

A dearth of material on industrial waste topics accounted for the relatively small editorial coverage of the subject in THIS JOURNAL prior to 1947. The recent gratifying but sudden increase in industrial waste papers has created a problem with respect to the capacity of the present bimonthly periodical, but no time is being lost in effecting a remedy. Publication of the JOURNAL on a monthly schedule will begin on January 1, 1950, making it possible for the Federation to meet fully its responsibilities in this direction.

Further evidence of the determination of the Federation to serve the waste control interests of industry lies in the action of the Board of Control at Detroit in October, 1948, when it instructed the Executive Committee to develop recommendations for a new name of the organization that will more appropriately connote its actual scope of activity. Suggestions will be welcome.

Operating as it should, this organizational network would leave the fundamental problems of waste reduction, recovery and treatment to the specialized technical knowledge and skill of each separate industry, combined and coordinated through the one or more trade or professional associations that serve the specific industry. The Federation would gather together the findings from such work and relay them to the pollution control authorities who interpret and evaluate the results in terms of effects on streams, to other industry groups having related problems, and to the designers and operators of the municipal sewage works that are receiving increasing amounts and types of industrial wastes. In return, the Federation would feed back to the industry service associations the latest information on stream standards, analytical methods, and on new advances and limitations in municipal sewage treatment. This is sound and practicable procedure.

The Federation is eager to fulfill its functions as here set forth. To date, only a few industry associations have undertaken to serve their constituencies in the development of waste control as a pollution abatement measure. All others are urged to assume the place that awaits them in this structure.

W. H. W.

Proceedings of Member Associations

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Spring Meeting

Marlborough, Mass., May 12, 1948

The 1948 Spring Meeting of the New England Sewage Works Association, held at the Marlborough Country Club, Marlborough, Mass. on May 12, 1948, was attended by 149 members and guests. Because of the illness of President LeRoy W. Van Kleeck, the meeting was presided over by First Vice-President Walter H. Brown, Jr.

The morning session was devoted to the following technical papers:

"Development of Marlborough Sewage Works," by Harry P. Loftus, Superintendent, Water and Sewage Commission, Marlborough, Mass.

"A Method of Treatment of Wool Scouring Wastes," by Joseph A. McCarthy, Chief of Laboratory, Lawrence Experiment Station, Mass. Dept. of Public Health.

"Cleaning a Sewer Clogged by Industrial Waste," by George W. Olson, city engineer, Woburn, Mass.

Following luncheon, Honorable Carlton W. Allen, mayor of Marlborough, extended the greetings of the city to the members and guests present. As after-luncheon speaker, FSWA Secretary W. H. Wisely gave a very interesting talk based upon his own experience and entitled: "Public Relations from the Operator's Standpoint."

The remainder of the afternoon was devoted to an inspection of the Marlborough sewage treatment plant, one of the oldest sand filter plants in Massachusetts, recently remodelled by the construction of grit chambers, comminutors, Imhoff tanks, high rate trickling filters, and final settling tanks. Past President Frank L. Flood, presiding at the microphone on a sound truck and explaining the various processes, assisted greatly in making the inspection exceedingly worthwhile for everyone. The use of a sound truck was tried for the first time, and it is believed that other member associations might find it equally useful.

WALTER E. MERRILL,
Secretary-Treasurer

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Twentieth Annual Meeting

Newport, R. I., September 9–10, 1948

The Twentieth Annual Fall Meeting of the New England Sewage Works Association was held at the Hotel Viking, Newport, Rhode Island, September 9 and 10, 1948. The total registration was 115 members and guests.

The morning program on September 9, presided over by President LeRoy M. Van Kleeck, opened with the annual business meeting, at which the following officers were elected for 1949:

President: Walter H. Brown, Jr., Cranston, R. I.
First Vice President: Ralph W. Horne, Boston, Mass.
Second Vice President: William S. Wise, Hartford, Conn.
NESWA Directors: Thomas A. Berrigan, Boston, Mass.; Prof. Edward S. Brown, Hanover, N. H.; John R. Szymanski, New Britain, Conn.
Secretary-Treasurer: Walter E. Merrill, Boston, Mass.

Technical papers presented at the morning session were:

"New Chlorinating Program at the Providence Sewage Disposal Works," by Howard F. Carpenter, superintendent, Providence, R. I.

"Unusual Accident Incidental to Sewer Maintenance," by Thomas A. Berrigan, director and chief engineer, Metropolitan District Commission, Boston, Mass.

Following luncheon the afternoon session was devoted to the following papers:

"High Rate Trickling Filter Pilot Plant for Industrial Wastes," by B. W. Dickerson, Hercules Powder Co., Inc., Wilmington, Del.

"New England Compact for Stream Pollution Control," by Walter J. Shea, chief, Division of Sanitary Engineering, R. I. Department of Health.

"Problems and Program of the Blackstone Valley Sewer District," by Charles G. Hammann, public health engineer, Blackstone Valley Sewer District Commission.

Following an excellent dinner, The Honorable John O. Pastore, Governor of Rhode Island, spoke most convincingly on the subject, "Little Rhody Tackles a Herculean Task." In closing he stated that if his administration accomplished nothing else, he would rid Rhode Island waters of pollution.

President Van Kleeck then called Past President F. Wellington Gilcreas to the head table and paid tribute to his past service to this association and extended the Association's congratulations on his receiving the FSWA Honorary Membership Award at the Detroit meeting. Mr. Gilcreas very gracefully turned the tables and on behalf of the association presented President Van Kleeck with a wrist watch for his long, faithful service as Secretary, Federation Director, and President of the NESWA.

The morning session on September 10 was devoted to the following papers:

"Recent Federal Legislation Relative to Stream Pollution," by Arthur D. Weston, director and chief engineer, Mass. Dept. of Public Health.

"Water and Sewerage Facilities at United States Naval Air Station, Quonset Point," by Lieut. Commander R. N. Crane.

"Sewage Flow and Characteristics at Cranston," by Henry Munroe, Builders-Providence, Inc., and Walter H. Brown, Jr., superintendent, Sewage Treatment Works, Cranston, R. I.

Following luncheon, through the courtesy of the Navy, the members of the association enjoyed a boat ride to the Quonset Naval Air Station, where they were met by buses and conducted around the Station for an inspection of the various facilities.

WALTER E. MERRILL,
Secretary-Treasurer

GEORGIA WATER AND SEWAGE WORKS ASSOCIATION

Seventeenth Annual Meeting

Atlanta, Ga., September 22–24, 1948

The Seventeenth Annual Meeting of the Georgia Water and Sewage Association was held at the Georgia Institute of Technology in Atlanta, Georgia, on September 22–24, 1948, in conjunction with the Georgia Water and Sewage School, which is conducted jointly by the Association, the Georgia Institute of Technology, and the Georgia Department of Public Health. Registration totaled 270 Water and Sewage Section members and visitors.

Blake R. Van Leer, president, Georgia Institute of Technology, in welcoming the association took the opportunity to stress to the membership their responsibility in the development of the water resources of Georgia, including flood control, recreation, water supply, industrial use of water, and protection of water sheds.

In leading off the technical program W. H. Weir, engineer, Georgia Department of Public Health, spoke on "Georgia's Water and Sewage Program," pointing out the necessity for careful and intelligent planning in the matter of water supply, sewerage, and industrial location if the streams are to be used to best advantage. He likened each river basin to a community where each must recognize and respect the rights of others in the matter of stream utilization.

Due to the presence of many new operators and a need for fundamental training, the Water and Sewage School considered basic studies of sewage treatment and water purification. "Chemistry of Water and Sewage" and "Chlorination of Water and Sewage" occupied the first afternoon with lectures by R. S. Ingols, associate professor, Engineering Experiment Station, Georgia Tech, and M. E. Henley, sales engineer, Wallace and Tiernan, Atlanta, Georgia.

Thursday, the second day, the School divided into two groups, basic and advanced, with about 60 per cent of the school attending the basic Group, conducted by N. M. deJarnette, engineer, State Board of Public Health, and H. A. Wyckoff, head, Department of Public Health, Georgia Institute of Technology. "Water Purification System Units and their Functions," "Bacteriology of Water and Sewage," "Chemical Laboratory Tests," and "Bacteriological Laboratory Tests," were their subjects of study. The advanced group heard a very interesting talk by Frank Binford, mayor of Thomaston, Georgia, telling how his city built a sewage treatment plant. Other interesting papers were "Water and Sewage Rates," by W. H. Weaver, manager, DeKalb County Water System; and "Improvements and Operation," by Bruce Hamler, superintendent, Water Department, Rome, Georgia.

Thursday afternoon a field inspection trip was taken to the Atlanta water purification plant, where additions are under construction, and to the new Smyrna sewage treatment plant. This plant, design capacity 0.24 m.g.d., was nicely landscaped and presented an exceptionally fine appearance.

The first paper of Friday morning's program, by Miss Elizabeth McEntire, bacteriologist, State Department of Public Health, told about the State Health Department's program of water examination. Other papers were:

"Maintenance of Electric Equipment for Water and Sewage Works," by A. R. Walker, Westinghouse; "Maintenance of Filter Equipment,"

by Charles Starling, Infilco; and "Water Main Sterilization."

The association's annual business meeting followed, during which committee reports were received and officers elected.

The Awards Committee presented the Frederick J. McMullin award and citation for meritorious work in the water works field to D. H. Hurst, superintendent of the water and sewage works, Tifton, Georgia; and the citation and award for outstanding work in maintenance and successful treatment results in sewage treatment to S. D. Love, superintendent of the Egan sewage treatment plant, Atlanta, Georgia.

Officers elected for 1948–49 were:

President: D. H. Hurst, city engineer, Tifton, Ga.

First Vice President: Clyde Angle, superintendent filtration, Celanese Corporation, Rome, Ga.

Second Vice President: Van P. Enloe, superintendent, Clayton sewage treatment plant, Atlanta, Ga.

Secretary-Treasurer: L. E. Waller, superintendent, South River sewage treatment plant, Atlanta, Ga.

The Friday afternoon meeting was devoted to a Sewage Works Round Table. The following subjects were discussed:

"Making Sewer Joints," by C. E. Shook, engineer, Wiedeman & Singleton, Atlanta, Ga.

"Making a Sewer Tap Without a Wye," by Ray Nixon, engineer, Sewer Department, Atlanta, Ga.

"Taking the Bang Out of Manhole Covers," by M. B. Nixon, superintendent, Sewer Department, Atlanta, Ga.

"Pumping Sludge," by Van P. Enloe, superintendent, R. M. Clayton sewage treatment plant, Atlanta, Ga.

"Trickling Filter Maintenance," by G. R. Frith, engineer, State Department of Public Health, Atlanta, Ga.

At the close of the school an examination was held for Class B and Class C water and sewage certificates by the Certification Committee of the Association.

VAN P. ENLOE,
Secretary-Treasurer

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Twentieth Annual Meeting

Minot, N. D., September 23–24, 1948

The Twentieth Annual Meeting of the North Dakota Water and Sewage Works Conference was held at Minot, North Dakota, September 23–24, 1948. Members and guests registered for the Conference numbered 116.

Mayor H. C. Kiehn welcomed the Conference members to Minot. Following R. J. Lockner's response, the annual business session of the Conference was held. Reports of officers and committee chairmen were presented. Fred J. Wells, chief, Fargo Fire Department, then addressed the Conference.

The afternoon session was devoted to professional and technical matters and the following papers were read:

"Minot Water and Sewerage Facilities," by J. Bliss, city manager, Minot.

"The Federation of Sewage Works Associations and the Detroit Convention," by George S. Russell, president,

Federation of Sewage Works Associations.

"Construction Practices for Asbestos Cement Pipe," by Jack Davis, Johns-Manville Company.

"Factors in Establishing Water Rates," by LeRoy Harlow, city manager, Fargo.

"The Development of a Sanitation Program in North Dakota," by Russell O. Saxvik, M.D., state health officer, Bismarck.

"Missouri River Basin Pollution Control," by Ralph Johnson, engineer, River Basin Pollution Control Office, U. S. Public Health Service.

The banquet session of the Conference was held Thursday evening and featured an address by Neal Tracy, Greater North Dakota Association. Mr. Tracy talked on the "North Dakota Water Program" and illustrated his remarks with colored moving pictures. He outlined irrigation projects now under way or planned for North Dakota, particularly the Pick-Sloan plan of control for the Missouri River. Colored motion pictures illustrated the progress of construction of the large Missouri River Dam which is being constructed near Minot.

The Friday morning session consisted of three group discussions:

The discussion group for sewage plant operators was presided over by Elder Lium, professor of civil engineering, University of North Dakota.

The water works operators group was led by John Oakey, professor of civil engineering, North Dakota Agricultural College.

The third group for general water and sewage operators had as its leader George J. Toman, consulting engineer, Mandan, N. D.

The annual Conference luncheon held at noon Friday was devoted to a business session in which committee reports were received and officers elected.

Officers elected for the 1948–49 year were:

President: George J. Toman, Mandan, N. D.
Vice President: A. F. Holteng, Grand Forks, N. D.
Secretary-Treasurer: Jerome H. Svore, Bismarck, N. D.
Conference Directors: Dean Colben, K. R. Johnson, and Gilbert Jung.

JEROME H. SVORE,
Secretary-Treasurer

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

Second Annual Meeting

Clarksburg, W. Va., Sept. 30, Oct. 1, 1948

The second annual meeting of the West Virginia Sewage and Industrial Wastes Association was held at Clarksburg, West Virginia, on September 30 and October 1, 1948. A total of 172 members and guests were registered.

The conference was opened Thursday afternoon in a joint afternoon meeting with the West Virginia Section of the American Water Works Association by Joseph Samples, chairman of the latter organization, who welcomed the sewage and industrial waste group. A response was given by P. D. Simmons, president, who presided during the remainder of the meeting.

The technical session was started with a paper by K. S. Watson, engineer-secretary, West Virginia Water Commission, entitled "The Ohio River

Compact and Others Operating in the United States." Information presented included a history of developments leading to adoption of the Ohio River Valley Water Sanitation Compact, a description of other compacts, and what action was expected.

"Fluorine and Tooth Decay" was presented by O. C. Hopkins, senior sanitary engineer, and Dr. Geo. A. Nevitt, senior dental surgeon, U. S. Public Health Service, District No. 2, Richmond, Virginia. Considerable discussion centered around the practical aspects of applying sodium fluoride.

Roy H. Ritter, partner, Whitman, Requardt and Associates, Baltimore, Maryland, presented a critical discussion on "Sewer Financing," with special emphasis on the problems involved in financing sewer construction at Martinsburg, West Virginia. An enthusiastic discussion emphasized the loopholes in state financing laws.

An excellent joint banquet was held Thursday evening with the water works group. J. K. Buchanan, vice-president, Monongalia Power Company, Fairmont, West Virginia, was the capable toastmaster. Vaudeville entertainment was provided after the banquet.

On the morning of October 1, the first paper was "Sewer Design," by Kenneth V. Hill, Greeley and Hansen, consulting engineers, Chicago, Illinois. The remainder of the morning was used in presenting the featured symposium —"Oxygen Balance—Assets and Liabilities." The subjects and authors were: "Introduction," by Dr. D. V. Moses, technical superintendent, E. I. duPont deNemours, Belle, W. Va.; "Sampling and Preservation," by Arch MacQueen, chemist, State Water Commission, Charleston, W. Va.; "Biochemical Oxygen Demand and Dissolved Oxygen," by C. C. Ruchhoft, head chemist, Stream Investigation Station, U. S. Public Health Service, Cincinnati, Ohio; and "Chemical Oxygen Demand and Oxygen Consumed," by Dr. K. M. Madison, senior fellow, Mellon Institute of Industrial Research, Pittsburgh, Pennsylvania.

During the 2-hour noon period the members were guests of the Universal Concrete Pipe Company for luncheon and an inspection trip of their manufacturing plant.

The first afternoon paper was "Industrial Wastes Definition and Records," presented by K. N. Bundy, assistant technical director, Wheeling Steel Corporation, Follansbee, West Virginia. Preston E. Jordan, technical director, Wheeling Steel Corporation, was co-author of this instructive presentation on how a large industry proceeds in defining its waste problem.

Herman F. Lundberg, Chester Engineers, Pittsburgh, Pa., followed with a detailed paper on "Plans for Clarksburg Sewage Treatment Plant."

The technical session was concluded with the paper "Coal Washery Waste Treatment and Recovery," by Henry F. Hubley, Pittsburgh Consolidation Coal Company, Pittsburgh, Pa.

At the business meeting the following officers were elected for the coming year:

President: J. E. Settle, Charleston, W. Va.
First Vice President: Ed. Shroyer, Fairmont, W. Va.
Second Vice President: Dr. D. V. Moses, Charleston, W. Va.
Secretary-Treasurer: R. G. McCall, Charleston, W. Va.

R. G. McCALL,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

See Page 196

Federation Affairs

TECHNICAL PROGRAM HIGHLIGHTS TWENTY-FIRST ANNUAL MEETING

The 21st Annual Meeting of the Federation at Detroit, October 18–21, 1948, proved to be one of the most successful meetings the Federation has enjoyed. Although not the largest Federation gathering in terms of numbers attending, the Detroit meeting was outstanding in the quality of its technical program, the interest of its equipment exhibits, and the relaxing entertainment provided by the social events. Particularly gratifying was the spirit of friendliness which pervaded the entire meeting.

Great credit is due the host Michigan Sewage Works Association, the Convention Management Committee, and the Local Arrangements Committee, headed by W. M. Wallace, for the careful and efficient manner in which the meeting was planned and managed. The precision and smoothness with which the various convention events were presented were the result of diligent and painstaking attention to detail by the various local committees.

Registration for the Detroit meeting totaled 749, of which 112 were ladies and 637 were men. While the total number at Detroit was considerably below the 812 attendance mark at Toronto in 1946, the number of men registered was greater than at any previous Federation meeting.

Geographically, representation at the 1948 meeting was well distributed throughout the country. Every section of the United States was represented as were all but three of the North American Member Associations. The Michigan Association took top honors with 176 registered. The Central States group was a close second, with the New York, Ohio and Pennsylvania associations represented by sizable delegations.

The 21st Annual Meeting was convened at 10:00 A.M. on Monday, October 18, 1948, by President George S. Russell. Commenting on the Federation's 1948 activities, President Russell reviewed the accomplishments of the year and underlined the areas in which Federation activity was planned for 1949. The presentation of the Executive Secretary-Editor's report by W. H. Wisely concluded the business portion of the opening session and was followed by an address of welcome by Hon. Eugene I. Van Antwerp, Mayor of Detroit.

Technical Program

The technical program developed by the Program Committee under the chairmanship of C. C. Larson, ably assisted by F. W. Gilcreas, was outstanding in quality and diversity of subject matter. The papers presented covered topics of broad interest to Federation members as well as subjects pertaining to specific stream pollution and waste treatment problems. Presented as a program feature for the first time at Detroit, the Industrial Wastes Forum attracted a great deal of interest and earned a definite place in future technical programs. The Operators' Forum, perennial program highlight, proved to be as popular as in the past. Discussion from the floor, developed around six vital operation topics, was spirited and instructive.

The technical program presented at Detroit was the same as the program announced in the Annual Meeting Preview carried in the September, 1948, JOURNAL on pages 937–939, with the exception of the addition of a paper by Col. W. L. Wilson, M.C., U.S.A. on "Integration of Administration of Medical Care for the Civil Population in Total War." All technical program papers will be published in 1949 issues of the JOURNAL.

Entertainment Events

An informal reception for Federation and the host Michigan association officers and wives opened the social program on Monday evening, October 18. Following the reception, a "family hour" of variety entertainment, featuring unusually clever professional talent, was enjoyed by an estimated 600 members and guests.

The Federation luncheon Tuesday noon was attended by 380 persons. President George S. Russell presided and presented the featured speaker, Kenneth L. Reid, Executive Director of the Izaak Walton League of America. Mr. Reid spoke on the subject: "Let's Be Realists About Pollution." In his talk Mr. Reid traced the growth of stream pollution control sentiment and discussed the recently enacted federal stream pollution control law. Frank Woodbury Jones, registrar of the Quarter Century Operator's Club, presented 16 members and several newly eligible members of the club, who were seated at special tables.

The Annual Federation Dinner and Dance, held in the Grand Ball Room Wednesday evening, October 20, proved to be the social climax of the meeting. With President George S. Russell presiding, the 435 members and guests attending the dinner were delighted with the beautiful singing of President Russell's son and daughter-in-law, Mr. and Mrs. Jess L. Russell, of Union City, Tenn. The remainder of the dinner program was devoted to President Russell's presentation of the annual Federation award. Dancing followed the dinner.

Ladies' Entertainment

The series of social events planned by the local Ladies' Entertainment Committee, under the chairmanship of Mrs. Virgil Anderson, was thoroughly enjoyed by the more than one hundred ladies attending the meeting. Particularly appreciated was the spirit of hospitality and friendliness with which the committee members welcomed the visiting ladies.

The Monday afternoon informal "get-acquainted" bridge party proved to be just that. The outstanding event of the week was Tuesday's luncheon at the famous Dearborn Inn and the tour through Greenfield Village which followed. The Ford Motor Company generously provided transportation for the ladies and arranged for guide service and complimentary admission to Greenfield Village.

Wednesday's full entertainment schedule started with the luncheon-style show at Hudson's, Detroit's well-known department store. A bus tour of Detroit and Windsor, Ontario, followed in the afternoon, with the Federation Dinner and Dance climaxing the day's activities.

Men's Inspection Trips

For the first time in 5 years, inspection trips were included in the program of the annual meeting. Wednesday afternoon's inspection trip to the Dearborn and Detroit sewage treatment plants was thoroughly enjoyed by the 232 men who made the trip. The sludge dewatering and drying process and equipment received particular attention from the visitors.

A specially arranged all-day industrial wastes inspection trip to Midland, Mich., where the Dow Chemical Company waste treatment facilities were observed, was provided on Thursday, October 21. Nearly 20 persons made

the trip which included a return stop at Ovid, Mich., where milk waste treatment facilities were visited.

Manufacturer's Exhibit

The interesting and informative displays of manufacturers and supplier's products, arranged by the Water and Sewage Works Manufacturers' Association, drew a great deal of attention and interest from those attending the convention. All of the available 52 booth spaces were utilized by the 30 manufacturers and suppliers who were represented in the exhibit.

Annual Michigan Dinner

The Michigan Sewage Works Association, host to the Federation meeting, held its 23rd annual dinner and business meeting Tuesday night, October 19, at the Hotel Prince Edward, Windsor, Ontario. This stag event was attended by 112 members and guests. With President T. J. Powers presiding, committee reports were received and association business transacted. Federation President George S. Russell conveyed to the group the Federation's official expression of gratitude and appreciation for the excellent manner the MSWA had carried out its responsibilities as host to the 21st Annual Meeting. Federation Vice-President-elect A. H. Niles and Executive Secretary-Editor W. H. Wisely also spoke briefly. Officers elected by the MSWA for the year 1948–49 were: *President*—A. T. Kunze, Wyandotte; *Vice-President*—Leonard Hillis, Caro; *Secretary-Treasurer*—Donald M. Pierce, Lansing; *FSWA Director*—L. F. Oeming, Lansing.

SIGNIFICANT BOARD OF CONTROL SESSIONS HELD AT DETROIT

In the importance of the actions taken, the annual Board of Control meetings held at Detroit on October 17 and 21, 1948, will rank with the meetings at which the Federation was created in 1928 and reorganized in 1941. Representation was quite satisfactory, with 32 of the 47 officers and directors comprising the Board in attendance.

President George S. Russell presided at the annual meeting of the 1948 Board on October 17, at which all reports of officers and committees were received. Later the same day the Election Committee met to name Victor M. Ehlers of Austin, Texas, as President, Arthur H. Niles of Toledo, Ohio, as Vice-President, W. W. DeBerard of Chicago, as Treasurer, and Carl E. Green of Portland, Ore., as Director-at-Large. The latter office is for a three-year term ending in October, 1951; all others are for the year 1948–49.

The organization meeting of the 1949 Board took place on October 21. With President Ehlers unable to attend because of convalescence from a recent serious illness, Vice-President Niles assumed the chair for this session.

Dues Increase to Accompany Monthly Journal

Of greatest significance was the decision to increase, as of January 1, 1950, the frequency of publication of SEWAGE WORKS JOURNAL from bimonthly to monthly. Simultaneously, the dues payable to the Federation for all Active Members are to be increased from $3.00 to $5.00 annually.

This action was mandatory because of the crucial situation that has developed with the bimonthly JOURNAL as a result of a 100 per cent increase in publishing costs since 1943 while the flow of material available and desirable for

publication is increasing each year. Printing and mailing costs alone—exclusive of editorial and overhead expenses—were $4.00 per member in 1947, $4.44 in 1948, and will be at least $4.63 in 1949. The Board noted that this rapid increase in unit cost per member was taking place in spite of a steady gain in membership. Moreover, the $24,000 printing budget adopted for 1949—the maximum possible in order to balance income and expenses—will be at least $3,000 less than that required to publish all of the good editorial material that will be available during the year.

Constitution and By-Laws Amended

Upon the recommendation of a special committee headed by Past President C. A. Emerson, a total of nineteen revisions in the Constitution and By-Laws were adopted, proper notice thereof having been given in advance. Only two of these were of real consequence, however, one creating a new Finance Committee as a constitutional committee and the other abandoning the so-called "Alternate Active" membership classification.

Change in Name of Federation to be Studied

The Board noted the increasing interest in the Federation on the part of representatives of industry, as a result of the greater emphasis given in recent years to industrial waste problems. In view of this trend, the Executive Committee was directed to recommend a change in the name of the Federation that will more appropriately signify the true scope of its activities.

Secretary-Editor's Report

The report of the Secretary for the year ended September 30, 1948 recorded the admission during the year of two new Member Associations, the Swiss Society of Water and Sewage Professionals and the Sewage Works Section of the Alabama Water and Sewage Association. Aggregate membership in the 34 Member Associations was 4,801 on September 30. This represented an increase of 15.4 per cent for the year.

Although a deficit of $3,500 for the year's operations was anticipated in in the 1948 budget, it was indicated that actual receipts would just about balance expenses. Reference was made to the inadequacy of the bimonthly JOURNAL under present conditions, and to the 20 per cent increase in advertising rates that is being initiated on January 1, 1949.

1948 Awards

In recognition of his "acknowledged eminence in one or more fields of activity within the scope of the Federation," F. Wellington Gilcreas was elected to the grade of Honorary Member.

The *Harrison Prescott Eddy Medal,* for outstanding research, was awarded to F. W. Kittrell and O. W. Kochtitzky, Jr., for their paper "Natural Purification Characteristics of a Shallow Turbulent Stream."

David P. Backmeyer was conferred with the *George Bradley Gascoigne Medal,* for an outstanding contribution in plant operation, in recognition of his paper "Operating and Experimental Observations on the Digestion of Garbage with Sewage Solids."

The *Charles Alvin Emerson Medal,* for extraordinary service to the Federation, went to LeRoy Winfield Van Kleeck, who has a long record of service in regular committees and in special assignments.

Of particular interest was the action of the Board in retiring the *Kenneth Allen Awards,* for service to Member Associations, as a result of a request by the New York State Sewage Works Association. A NYSSWA award of the same name antedates the Federation award, and the prior right of the New York unit of the Federation was recognized. Beginning in 1949, the Federation will offer a new *Arthur*

Sidney Bedell Award for notable service to Member Associations, in honor to the memory of its second president.

The 1948 *Kenneth Allen Awards,* the last to be given by the Federation, were granted to George W. Marx (Arizona), David B. Lee (Florida), William Q. Kehr (Missouri), F. Dean Stewart (Ohio), and Francis S. Friel (Pennsylvania).

Recipients of the *William D. Hatfield Awards,* for outstanding plant operation reports, were Kerwin L. Mick of Minneapolis-St. Paul, Thomas T. Hay of Racine, Wis., and F. E. Peterson of Belvidere, Illinois.

Twenty-Year Index Authorized

The headquarters office was authorized to proceed in 1949 to produce a comprehensive index covering the first twenty volumes of SEWAGE WORKS JOURNAL. The index will be bound in cloth and will be sold at a moderate price.

Accounting Manual

Publication in mimeographed form was directed of a tentative manual of practice entitled "Sewage Works Accounting." This manual was developed by a special committee headed by F. M. Veatch; the limited number of copies to be printed will be placed on inventory for sale only.

Committee Activities

Several noteworthy developments were recorded in the numerous committee reports presented to the Board.

The "Standard Methods" committee advised of the renewal grant of $48,700 made by the National Institute of Health, to continue the analytical methods research project originated in 1947. The work will be conducted in seven laboratories in 1948–49, including the Illinois State Water Survey, the New York State Department of Health, Massachusetts Institute of Technology, the University of Wisconsin, Purdue University, Rutgers University, and Ohio State University.

The Research Committee announced the creation of a new Subcommittee on Toxicity of Wastes. This group will gather information on the effects of toxic substances on sewage treatment processes, aquatic life, and on the B.O.D. test.

The Glossary of Water and Sewage Control Engineering, being produced jointly by the Federation's Committee on Sewage Works Nomenclature with similar committees of AWWA, ASCE and APHA, is expected to be ready for distribution by January 1, 1949. Reconsideration of the original plan to furnish complimentary copies of this publication to all members of the participating organizations appears likely to result in a change to distribution by sale only, through ASCE headquarters.

The Committee on Operation Reports secured approval of a new set of rules covering the Hatfield Awards competition. These are published in full elsewhere in this issue.

Creation of a new Committee on Sewer Revenue Rates and Rate Structures was directed, which committee is to guide Federation policies on revenue financing and direct them to the attention of the committee that has been established jointly by the ASCE and American Bar Association to study fundamentals of water and sewer revenue rates. The Federation is represented in the latter body by Past President George J. Schroepfer.

Minneapolis–St. Paul in 1951

Subject to final determination as to adequacy of hotel accommodations, the Board acted to designate Minneapolis-St. Paul as the site of the Twenty-fourth Annual Meeting of the Federation in 1951.

V. M. EHLERS ASSUMES FSWA PRESIDENCY

V. M. Ehlers of Austin, Texas, became the ninth President of the Federation at the 1948 Annual Meeting of the Board of Control at Detroit, October 21, 1948. Having suffered a severe illness prior to the meeting, Mr. Ehlers' convalescence had not progressed sufficiently to permit his attendance.

Following his early education in the public schools of La Grange, Texas, Mr. Ehlers graduated from Texas A. & M. College in 1905, receiving a B.S. degree in Civil Engineering. In 1910 he received his professional Civil Engineering degree from Cornell University.

Immediately following graduation from Texas A. & M., Mr. Ehlers was engaged by various railroad companies and by the Stone and Webster Engineering Corporation. From 1910 to 1915 he served as construction engineer with the Southern Pacific Railway Company of Mexico, as engineer with Stone and Webster Corporation, and as construction engineer for several water and sewage works systems in Texas.

In 1915 Mr. Ehlers was employed as the Chief Sanitary Engineer of the Texas State Department of Health, a position he still holds and which he has filled with distinction. During his career he has become one of the nation's leading sanitary engineers and has contributed greatly to the expansion of sanitary engineering programs in Texas. The recipient of many honors, Mr. Ehlers has served as Vice-President of the American Public Health Association; Chairman of the Conference of State Sanitary Engineers; President of the International Association of Milk Sanitarians; and Consultant to the U. S. Public Health Service. He has also received the Fuertes Award from Cornell University for his contribution to sanitary science, and the Fuller Award from the Southwest Section of the American Water Works Association.

Mr. Ehlers is the author of several sanitary engineering textbooks. He is also the founder and guiding genius of the Texas Water Works and Sewerage Short School, which is one of the oldest and largest of such organizations in the United States. In 1940 Mr. Ehlers was appointed by the President of the United States to the Committee on Inter-American Cultural Relations of the Department of State and is now a member of one of the committees of the Good Neighbor Commission. He has assisted in the formation of numerous health and welfare organizations in the United States and has lectured at many leading universities and colleges.

For over 20 years Mr. Ehlers has been active in Federation affairs, having served on the "Committee of One Hundred" which planned the original organization of the Federation. He was a charter member of the Board of Control, on which he served continuously from 1928 to 1942. His past service on the Organization, Coordinating Publicity, and Executive Committees is indicative of the broad and vital contribution he has made to the success of the Federation.

During his term as Vice-President, Mr. Ehlers was a member of the Executive Committee and the Legislative Analysis Committee. Mr. Ehlers' many years of experience, leadership, and service will contribute greatly to the Federation's continued progress in 1949.

A. H. NILES BECOMES FEDERATION VICE-PRESIDENT

As Engineer-Manager of the Division of Sewage Disposal of Toledo, Ohio, Vice-President Arthur H. Niles brings to the Federation leadership a thorough understanding and appreciation of the practical problems of plant operation personnel.

Mr. Niles's activity on Federation committees bespeaks the quality of his technical accomplishments and administrative ability. Mr. Niles has served on the Board of Control since 1942 and has been a member of the General Policy Comittee from 1946 to date. He also has served on the Sewage Works Practice Committee for eight years. As chairman, and later co-chairman, of the Subcommittee on Utilization of Sludge as Fertilizer, Mr. Niles supervised the collection of the preliminary data and preparation of the first draft of Manual of Practice No. 2. He also assisted materially in preparing this manual for final publication.

Since 1932 Mr. Niles has been Engineer-Manager of the Division of Sewage Disposal of Toledo, Ohio. During this period he became one of the leaders of the Ohio Sewage and Industrial Wastes Treatment Conference, serving on numerous committees. He was president of the Conference for two successive years and in 1948 completed a 3-year term as the Ohio Board of Control representative. Mr. Niles brings to his new Federation position a rich professional experience, first-hand knowledge of member and member association problems, an enthusiasm tempered with understanding, and proven qualities of leadership.

F. WELLINGTON GILCREAS ELECTED HONORARY MEMBER

At the 1948 Board of Control Meeting in Detroit, F. Wellington Gilcreas was elected an Honorary Member in recognition of his long years of outstanding and loyal service to the Federation. By this action Mr. Gilcreas becomes the tenth individual to receive this highest of Federation honors.

Mr. Gilcreas was graduated from Harvard University in the class of 1916 and thereafter spent several years as water analysist and chemist with the Division of Laboratories of the New York State Health Department. Following 10 years of employment as chemist with Weston and Sampson, Boston, Mass., consulting engineers, Mr. Gilcreas returned to the New York Health Department Division of Laboratories in 1934 where he has served as associate chemist and, since 1944, assistant director. Under both titles he was and is in charge of all sanitary and analytical chemistry activities of the Division.

Mr. Gilcreas' greatest contribution to the Federation has been made through his work as Chairman of the Publications Committee in which position he served from 1941 to 1948. During these years he guided the publication activities of the Federation and served as Chairman of the Program Committee for the Federation Annual Meetings. More than any other individual Mr. Gilcreas has been responsible for the excellent technical programs which have been a feature of all Annual Meetings.

Mr. Gilcreas has also served the Federation as a member of the Standard Methods and Sewage Works Practice

Committees and has contributed materially to the administration of the Federation during his 10 years as a member of the Board of Control. In recognition of his service he was awarded the Charles Alvin Emerson Medal in 1946.

Always interested in the activities of the Federation member associations, Mr. Gilcreas has been a long time member of the New York Sewage Works Association and the New England Sewage Works Association. He has served both organizations with distinction, receiving the Kenneth Allen award in 1944 from the New England Association.

NEW RULES FOR OPERATION REPORT COMPETITION

Among other actions, the 1948 Board of Control in session at Detroit adopted the revised rules for the William D. Hatfield Awards which were submitted and recommended by the Committee on Operation Reports. The Committee's recommendations were the outgrowth of a long and careful study and were developed in order to make the competition for the awards more attractive and practicable.

The rules which now govern the William D. Hatfield Awards are as follows:

A. Purpose of Awards

The purpose of the William D. Hatfield awards is to encourage operators of sewage and waste treatment plants to prepare, publish and distribute annual operating reports which are necessary or desirable for the following purposes:

1. To serve the interests of public relations.
2. To provide a means whereby the operator may make a businesslike accounting of the expenditure of funds and care of the treatment plant and accessories entrusted to him.
3. To serve the report requirements of the operator's superior officials.
4. To serve generally as a basis for recommendations made by the operator for improvements to his plant to secure better efficiency and economy of operation of higher degrees of treatment.
5. To advance the art and knowledge of sewage and waste treatment through making available to other engineers and operators the basic information and data concerning operation of a particular plant which is needed for study or appraisal purposes as related to proposed new developments or changes in operating procedures or methods elsewhere.

B. Three Awards May be Granted Each Year

A William D. Hatfield award may be granted each year upon recommendation of the Operation Report Committee and approved by the Board of Control to an operator in each of the following categories, who is adjudged to have submitted the best annual report on plant operation, judged in accordance with the schedule presented herein:

1. Operators of plants serving less than 10,000 population or population equivalent.
2. Operators of plants serving 10,000 to 100,000 population or population equivalent.
3. Operators of plants serving more than 100,000 population or population equivalent.

Operators of industrial waste treatment plants as well as operators of municipal sewage treatment plants are encouraged to compete.

C. Procedure For Submitting Reports

To enter the competition during any year:

1. The annual operating report must be printed, mimeographed or typewritten and must cover a period of 12 months of operation beginning with some month within the

24 months immediately preceding July first of the year for which the award may be granted. That is, reports eligible for the 1949 award shall cover 12 consecutive months of operation between the periods of July 1, 1947 and December 31, 1948.

2. Five (5) copies of the report must be submitted by the competing operator to the Secretary of the Federation of Sewage Works Associations not later than June 1 of the year in which the competition is entered. No entries will be considered which are received later than June first.

D. Procedure For Routing Reports To Operation Reports Committee

1. Upon receipt of above 5 copies of report from any competing operator, the Secretary of the FSWA shall transmit one copy thereof to each member of the Operation Reports Committee for rating in accordance with the schedule presented herein.

2. Prior to September 1 of each year, each member of the Operation Reports Committee shall sent to the Chairman of said committee the ratings of the reports made by such committee member. The ratings shall be given in percentages for all reports entered in each of the three categories specified in Section B above.

3. Upon receipt of the ratings reported by individual members of the Operation Reports Committee the Chairman shall add thereto his own ratings. The final rating of any report shall be determined by taking the average ratings for such reports as made by all members of the Committee. In each category the reports achieving the highest average rating as made by the several members of the Committee shall be adjudged to be the winning report in such category.

4. In case of a tie, duplicate awards will be made.

5. No award will be made to any operator who achieves a final rating of less than 70 per cent on his report.

E. Rating Schedule

Judging of reports shall be in accordance with the following schedule:

Item	Maximum Percentage Points
1. If report is printed or duplicated by mimeograph, etc.	5
2. General format of report—appearance, attractiveness, binding, use of illustrations such as charts or photographs	10
3. Contents or text of report, covering the following items:	
a. Introduction giving purpose and some historical background of plant	5
b. Description of treatment works	10
c. Pertinent data concerning design and actual loadings of plant	10
d. First cost and operation cost data	10
e. Plant performance data based upon analytical and other records	15
f. Evaluation of operating data	5
g. Effects of effluent on receiving waters	5
h. Statement of operating problems	5
i. Statement re: research, training activities or public relation matters	5
j. Maintenance program	5
k. Conclusions or recommendations	10
Total	100

PENNSYLVANIA AND WEST VIRGINIA ASSOCIATIONS WIN MEMBERSHIP CONTESTS

The 1948 Federation membership contests, carrying prizes of $100 each, were won by the Pennsylvania Sewage and Industrial Wastes Association and the West Virginia Sewage Works and Industrial Wastes Association. Both contests covered the year ended September 30, 1948.

The numerical increase of 135 members enrolled by the Pennsylvania Association is believed to represent the greatest growth ever to be recorded in a year by any FSWA Member Association. Most of the new members are representatives of industry, reflecting the commendable emphasis in Pennsylvania on problems of industrial waste treatment and disposal.

No previous Federation membership prize has ever been so closely contested as the 1948 percentage increase competition. Taking advantage of the fact that its annual meeting was underway on September 30, the West Virginia Association waged an intensive campaign and filed a list of 36 new members by telephone three hours before the close of the contest. The final West Virginia increase of 198 per cent was sufficient to overcome a gallant effort by the Kentucky-Tennessee unit, which had recorded a gain of 169 per cent.

Other associations meriting honorable mention for 1948 membership activity are Texas, with an increase of 74 members (117 per cent); Ohio, which gained 63 members (37 per cent); Pacific Northwest, with a gain of 39 members (30 per cent); and Federal, with an increase of 31 members.

Of the 34 Member Associations in the Federation on September 30, only five failed to record a gain in membership for the year. In only one case was there an appreciable loss.

ALABAMA ASSOCIATION JOINS FEDERATION

Amendments to the constitution of the Alabama Water and Sewage Association, approved at its Third Annual Conference at the Alabama Polytechnic Institute (Auburn) on June 11, 1948, consummated creation of a Sewage Works Section for the purpose of affiliation with the Federation. Since the Board of Control had approved the application in advance at the 1947 Annual Meeting, the new Sewage Works Section took its place immediately as the thirty-fourth FSWA Member Association.

The move was planned and negotiated by a special committee consisting of R. C. Barton, Chairman, A. N. Beck, Prof. G. H. Dunstan, P. B. Krebbs, Prof. T. M. Lowe, and Cecil Nabors.

Twelve charter members were enrolled at the organization meeting of the Section, as follows: R. C. Barton, A. N. Beck, J. C. Clarke, G. N. Mitcham, W. F. Chandler, Jr., C. L. Gray, L. L. Jordan, Alex O. Taylor, E. C. Alford, C. W. White, John E. Gran and G. H. Dunstan. Mr. Barton, who is Sanitary Engineer for the Jefferson County Commission (Birmingham), was named as Director to represent the Section on the FSWA Board of Control.

Under the amended constitution of the Alabama association, the Sewage Works Section is administered by the officers of the parent organization. These are, for the year 1948–49, Tom Collins, President; Geo. H. Godwin, Vice President; Prof. Alex O. Taylor, Secretary, and Prof. Gilbert H. Dunstan, Treasurer.

The inclusion of Alabama within the national territory of the Federation leaves only six states—South Carolina, Louisiana, Mississippi, Nebraska, Utah and Nevada—outside the fold. Preliminary steps are now being taken, however, in South Carolina and Louisiana, and the affiliation of existing organizations in those states is anticipated within a year or two.

Reviews and Abstracts*

The Control of Psychoda Fly in Biological Filters of Sewage Disposal Works. By J. A. McLachlan and Elizabeth Hogg. *Public Health*, **12**, 7, 197 (July, 1948).

The authors review the life cycle of psy. *alternata* and psy. *severini* and outline some of the methods commonly employed to control trickling filter flies. Various experiments on plant filters 100 ft. diameter and 6 ft. deep were made to determine feasibility and efficiency of Gammexane as a means for controlling psy. *alternata* and psy. *severini*. Control filters were operated parallel with filters which were dosed with different amounts of Gammexane. Fly trap observations and observations for larvae on the stones were used to determine the effectiveness of the chemical. Gammexane was applied at the filter dosing tank in amounts varying from 0.34 to 0.68 lb. per filter for intervals varying 24 hours to 6 hours, giving a concentration in the sewage of 0.1 to 0.5 p.p.m. Also 0.68 lb. per filter was applied during 20 minutes as a shock treatment. The filters were rested for different periods up to 18 hours after treatment. Tests were made to determine the effect on the oxygen absorbed and on nitrate nitrogen.

Individual doses of the chemical controlled the fly problem for periods up to 21 days after dosing. Other experiments indicated that continuous application of small amounts of Gammexane to the sewage being applied to the trickling filter might control the flies. The observations showed that *Achorutes* and certain mites and worms were also reduced.

From their results the authors report that Gammexane is the most convenient, effective and economical treatment for the control of Psychoda which they have experienced. Gammexane appeared to have no deteriorating effect on the plant effluent at any time. When using the shock dose treatment it is necessary to rest the bed for a short time following the application but this did not seriously upset normal operations of the plant.

H. B. Gotaas

The Preparation of Hydraulic Diagrams. By L. B. Escritt, *Journal of the Institution of Sanitary Engineers*, **XLVI**, Part 4, 113–123 (December, 1947).

This article deals with plotting various empiric hydraulic formulae of the form $Y = CX^n$ on a logarithmic scale where they plot as a straight line equation, $\log Y = \log C + n \log X$. The convenience and usefulness of these diagrams in solving equations of this type is illustrated.

Discussion of the geometry as well as the graphical technic for the preparation of hydraulic diagrams is given. Diagrams are developed for the basic or sample formulae of the 90° V-notch weir, the flat-crested weir, and circular pipes and culvers having only three variables.

Equations of more than three variables are difficult to conveniently plot on one chart. It has been done by superimposing additional diagonals or adding distorted scales which become confusing. The development and use of "linked diagrams" which involves the linking of two diagrams by a common series of lines is described and illustrated. One set of three linked diagrams can be made to provide any desired range of calculations for a particular flow formula. Since the slopes of the diagonals on the chart are determined by the exponent (square root) of the channel gradient in the formulae, and since there is no square root concerned in "n," it is either necessary to distort the scale of "n" or change the slope of the diagonal. In these figures the slope of the diagonal was changed.

H. B. Gotaas

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

The Design of a Trade Waste Sewer, with Special Reference to the Chemical Resistance of Pipe Joints. By A. J. Wigley. *Journal Institution of Civil Engineers*, April, 1948, No. 6, 1947–1948, pp. 196–200.

An 18-in. concrete sewer pipe 2 miles long was destroyed by trade wastes in 4 years. A study was made on replacement. The flow comprised about 360,000 Imp. gal. per day, plus 2,000,000 Imp. gal. per day from a pharmaceutical chemical works. The wastes varied, with frequent flushes of acid or alkaline waste—at times containing the equivalent of 1¼ per cent sulfuric acid, or as much as 1 per cent of caustic soda. Neutralization of 24-hour flow by mixing proved impractical. Neutralizing of the unbalanced flow is planned.

After acid resistance tests, glazed stoneware pipes were chosen instead of chemically resistant glazed stoneware. A joint material was sought to withstand acids, alkalies, and organic compounds. The materials available were (1) hydraulic cements; (2) acid-resisting cements (based on soluble alkali silicates); (3) rubber latex cements; (4) lutes; (5) bitumen; (6) synthetic resin cements.

A proprietary cold-setting synthetic resin cement was adopted, which has a barium sulfate filler, with a bakelite binder, mixed on the job. A 27-inch joint cost four pounds ($16.00), requiring 2 to 5 days to set. A coat of bituminous paint was given.

The sewer was 27 inches for two-thirds its length, 30 inches for the balance. Half a mile was laid through a peat bog on reinforced concrete piles. The bog water contained the equivalent of from 680 to 1,300 p.p.m. of calcium sulfate. In the higher content, all concrete was made with aluminous cement.

Langdon Pearse

Annual Report of the City Engineer of Johannesburg, South Africa, for Year Ending June 30, 1947. By H. Schrader.

The total flow to five treatment works was around 20,000,000 Imp. gal. per day. At the Bruma works, trade wastes caused a thick scum in the settling tanks. At Cydna, the return of a small quantity of final effluent (humus tanks) to the influent of the trickling filters was helpful. At Klipspruit, 12,632 lb. of hard soap and 3,100 lb. soft soap were made from by-products.

Farming operations continued, using effluent for irrigation in raising hay, Italian rye grass, oats, and mealage. Cattle are bred, fed, and sold at a profit. Some sludge was sold.

The revenue, in pounds, was derived from:

Sludge	2,586
Farm Produce	4,836
Grazing	15,704
Cattle	5,083
Water and Effluent	170
Pound Fees	1,040
Dipping Cattle	21
Rents	387
Soap	314
	30,141

Two papers are included in the annual report:

(1) "Scum Formation on Primary Settling Tanks a Peculiar Industrial Waste Problem." By J. A. McLachlan, pp. 39–51;
(2) "Removal and Disposal of Solids from Sewage." By J. Samson, pp. 52–55.

The scum which forms on the primary settling tanks (Bruma Works) is gray in color, containing mineral oils, yeast wastes, etc., and activated sludge. Gas bubbles are entrained, containing nitrogen (sometimes 64 per cent) and methane (21 per cent). Preliminary investigations indicated:

(a) Activated sludge is not the causative factor, but may aggravate.
(b) Scum is associated with gassing.
(c) Settled supernatant is not responsible.
(d) Most practical remedy was to mix waste activated sludge with strong sewage and avoid intermittent return of large volumes of waste sludge.

The final conclusion was that high nitrites and nitrates were present in the raw sewage, due to soluble nitrates from the manufacture of white lead. Such wastes may contain up to 3,200 p.p.m. of N and 24,000 p.p.m. of $PbCO_3$. Nitrogen gas was evolved by reduction of nitrate, due to bacterial activity of the sewage solids. Rising sludge occurs when nitrate or nitrite concentration exceeds 5 p.p.m.

of N. In one outfall sewer, over 1,000 p.p.m. nitrate nitrogen were found.

At Bruma, waste activated sludge is fed into a sump, mixed with sewage which at intervals is pumped into the main sewage flow prior to settling. Warm temperature in settling tanks promotes gas production. Apparently the mixture of nitrate or nitrite and sludge, plus sewage, produces nitrogen gas. Both activated sludge and raw sewage solids are potent denitrifiers.

The remedial measures suggested are:

(1) Modification of method and times of wasting activated sludge to the sewer.
(2) Advising industry to reduce discharge of nitrate and lead ions.
(3) Partial sterilization of waste activated sludge by chloride of lime in amounts not less than 230 p.p.m., somewhat higher than Brandon and Grindley (*Surveyor*, **104**, 2763, 7 (1945)), used on waste from shell loading factory, where 20 p.p.m. of chlorine were required (approximately 60 p.p.m. bleaching powder) to prevent rising of sludge.

LANGDON PEARSE

Melbourne and Metropolitan Board of Works (Australia), Report for Year Ended June 30, 1947.

The Board provided new sewers for 5,435 buildings during the year, despite a shortage of labor. However, on the extension of the main drainage works, construction practically ceased for many months. The metropolitan farm (area 24,579 acres), situated 24 miles southwest of Melbourne, receives over 99 per cent of the sewage flow. Livestock are grazed and sold. The cost of sewage purification and disposal was 121,093 pounds ($484,372), or a net cost of two shillings and one penny (42 cents) per capita served. 5,457 head of cattle were sold. On June 30, 1947, there were 13,453 cattle on the Farm.

Since 1892, over 600,000 seedling trees have been planted, principally eucalyptus and pines.

LANGDON PEARSE

Progress of Pollution Abatement in the Tennessee Valley. BY W. G. STROMQUIST. *Paper Trade Journal*, **124**, 20, 41–42 (May 15, 1947).

Stream pollution in the Tennessee River system originates mainly in the upper part of the valley with municipalities and industries in Virginia, Tennessee, and North Carolina. In 1945 Tennessee, and in 1946 Virginia, passed stream pollution laws and established control boards. North Carolina has organized a Sanitation Committee to obtain factual data on which to base stream pollution legislation.

The Tennessee Control Board organization and personnel and its procedures for issuance of tolerance permits are outlined. The Board's policy is to cooperate with municipalities and industries and to use the teeth of the law only in extreme cases.

The Board's technical personnel has concentrated its first work on the Holston River Basin in Northeastern Tennessee, which contains 5.3 per cent of the state area but has 18 per cent of its industrial pollution. Also, this river has a relatively low dry-weather-flow. The TVA has cooperated with use of its mobile laboratory.

The Board's technical committee has written a report which includes minimum criteria of water conditions in terms of solids, temperature, turbidity or color, taste or odor, acidity or alkalinity, hardness or mineral compounds, dissolved oxygen, toxic substances, and other pollutants. These criteria are applied to streams below known points of pollution and based on available dry-weather-flow data at a certain point, the stream flow to be adjusted to other points. All these data will be used to determine the degree of treatment necessary for domestic sewage and industrial wastes by using the adsorptive capacity of the stream as much as possible.

Descriptions are given of three instances of cooperation between the State Agencies, the TVA and pulp, paper, and paperboard companies, and a company manufacturing copper and sulfuric acid. The wastes from the Mead Corporation's paperboard mill at Harriman, Tennessee during certain seasons of the year caused serious problems from taste, odor, and color in the municipal and domestic water supplies. The corporation constructed a lagoon for storing the digester liquor and installed a Dorr clarifier to settle suspended solids in the white water after it had been treated with lime. The digester liquor and the lime-sludge are barged downstream to the main Tennessee River and discharged over a

large area. These are temporary expedients to reduce the objectionable pollution while extensive researches are in progress to develop methods for (1) burning the digester liquor for recovery of sodium carbonate, and (2) dewatering the lime sludge so that it can be made into agricultural lime.

The Champion Fibre and Paper Company has underway a $5,000,000+ paper mill construction program at Canton, N. Carolina. It is estimated that about ⅓ of the expenditures will be for structures and equipment to reduce waste discharges from the existing and the new mill. This will abate pollution of the Pigeon River, a tributary of the Tennessee River.

The Ecusta Paper Corporation is cooperating for reduction of pollution of the French Broad River. There was remarkable correlation of stream survey data obtained independently by personnel of this company and of the TVA trailer laboratory and U. S. Public Health Service. In applying Prof. Velz' formula for reoxygenation of streams, it was found that the coefficient "*k*" which he generally reported as about 0.1 was as high as 0.6. Prof. Velz' work had been on streams at least 5 ft. deep, having low velocities. The French Broad River is comparatively shallow, turbulent, and of very high velocity. Hence, such a stream may in some instances require a less degree of treatment of sewage and industrial wastes than would be required under different conditions.

Another example of very helpful cooperation was by the Tennessee Copper Company. When it was observed that the turbine runners in one of the TVA hydroelectric plants were badly corroded after only a few months of service, this Company improved the recovery of the SO_2 from the roasting of copper ores. Thereafter the quality of the water in the Ocoee River was much improved. While there has been considerable abatement of water pollution, much remains to be accomplished.

W. W. HODGE

Annual Report, Commissioner of Public Works, City of Fitchburg, Mass. 79 pp. 1947.

This report contains data on the operation and maintenance of the sewage disposal plant for the year 1947. The flow treated averaged 3.95 m.g.d. on a population of 42,000, with a maximum of 4.73 m.g.d. and a minimum of 3.21 m.g.d. The average detention period in the Imhoff tank was 5 hr. 46 min.; the design period 3 hours. The average per capita flow was 93.6 g.p.d. The design basis was 125 g.p.d.

The trickling filter in use was 1.86 acres, receiving 2.12 m.g. per acre per day (designed for 2 m.g.d.). Eleven nozzles were cleaned daily. The plant was designed to serve 55,000.

The surface of the Imhoff tanks was flushed frequently and the gas vents cleaned during the summer and fall. The flow of sewage was reversed once a month. During the year, 825,000 gal. of sludge were pumped. The skimmings averaged 3 cu. ft. per day. 80 per cent of the sludge was air-dried, the balance going to lagoons. The drying beds were cleaned twice during the summer and fall. 12 inches of sand were placed on ten of the beds.

There was no evidence of pooling on the trickling filter. The dosing tanks were cleaned twice. The secondary tanks are pumped once a month in the summer and fall to two special beds. The screenings from the bar screen at the siphon averaged 1 cu. ft. per day.

The cost of personal service was $14,500; expenses $2,174 (including taxes of $358.00).

LANGDON PEARSE

Grazing of Cattle on Sewage Farms and Disposal Works. *Public Health* (Official Journal of the Health Officials' Association of Southern Africa and of the Institute of Sewage Purification (S. A. Branch)), pp. 76–88, March, 1948.

The article is in the form of a symposium with information being contributed by A. L. Abbot, city chemist of Cape Town, several veterinarians, and other personnel apparently connected with sewage disposal facilities at Johannesburg in South Africa. Most of the information presented relates to the hazards or lack of hazards of grazing beef and dairy cattle on pasture land irrigated with settled or more completely treated sewage.

It is the consensus of opinion that consumption of sewage effluents by cattle has

no harmful effect on milk production or disease incidence, and introduces no possibility of milk contamination except indirectly from unhygienic dairy procedure. The positive advantages of irrigating grazing land with sewage include utilization of valuable fertilizing material and irrigating water as well as providing a satisfactory sewage disposal method that produces revenue to partially offset sewage works costs.

In the discussions the point is strongly made that there is ample evidence proving the harmlessness of consumption of sewage by cattle and that "sewage poisoning" does not exist. Information is also presented showing that grazing of cattle on sewage farms has no harmful effect on volume of milk produced, rate of worm infestation, or incidence of tuberculosis, mastitis, and contagious abortion.

At the Cape Town sewage works, where cattle have been grazed for 20 years, normal grazing procedure is as follows:

1. Cows in milk are not grazed because of the charges that would undoubtedly be made against the city in the event of a milk-borne disease outbreak.
2. Fresh drinking water for the stock is supplied either in the pasture or in the night paddocks.
3. At the Athlone sewage works, where the pastures are irrigated with a completely treated effluent, from one week to a month elapses between cessation of irrigation and commencement of grazing depending upon the season of the year.
4. At the Wynberg works where raw sewage is discharged directly to the pastures, the period between irrigation and grazing is at least 2 weeks in summer and as much as 6 weeks in winter.

The revenue from grazing at the Klipspruit sewage farm of Johannesburg, where settled sewage is used for irrigation, is reported to have averaged £10,000 per year and the value to the cattle owners is estimated to be £50,000 per year. A new section of this farm, first used in 1942, produces fodder crops for final fattening of cattle in addition to providing more pastures for grazing.

M. R. Golly

Biological Treatment of Deinking Waste. By Philip F. Morgan. *Paper Trade Journal*, **126**, 20, 41 (May 13, 1948).

The disposal of deinking waste presents serious pollution problems in a number of receiving streams. Reference is made to the pioneer researches on the properties and methods for treatment of deinking waste liquors carried out by the National Council for Stream Improvement Fellowship established at Mellon Institute in July 1944. The more objectionable properties of some 30 samples of deinking waste investigated * were: turbidities ranged from 1,000 to 3,200 p.p.m.; suspended solids varied from 570 to 3,072 p.p.m., with 30 to 42 per cent being volatile; B.O.D. was removed by plain settling, filtration, centrifuging, or by any of the many different chemical coagulants or combinations thereof applied.

To be nearer sources of deinking waste, the further development of the bioaeration process for treatment of deinking waste was transferred to the National Council's Kalamazoo College Fellowship in April, 1946. The aeration experiments described in this paper were conducted in five stoppered, 1-gal. glass bottles (called *tanks*) set in an inverted position with the bottoms cut out. The B.O.D. of the deinking waste used averaged 485 p.p.m., with a variation of 134 to 739 p.p.m. Average pH after settling and storage was 8.8, as used, the pH usually being 0.2 to 0.4 higher when freshly collected. Air flowing to each tank at the rate of 0.12 to 0.13 cu. ft. per. min., as measured by calibrated short tube orifices, was passed into the waste liquor through a 1-in. carborundum diffuser placed near the bottom of each tank. A photo of the set-up is given. The investigation was carried on for 1 year, and quite satisfactory results in removal of B.O.D. were obtained.

The three tanks first started were fed only once a day with 1,000 ml. of raw deinking waste. The waste in one tank was seeded with 25 per cent settled sanitary sewage; in another tank, with 25 per cent water drained from rich bottom land mud; the third tank contents were diluted with 25 per cent tap water. The results of one week's operation showed that the excessive quantities of settleable solids in the raw

* This Journal, **19**, 5, 830 (Sept. 1947).

waste made it impractical to develop a satisfactory biological life. Thereafter the feed was changed to settled waste, which was obtained by allowing the suspended solids in the freshly collected raw waste to settle for 1 hour and then siphoning off the settled waste. After 3 weeks' operation at this low feeding rate the determinations of B.O.D. of the effluent indicated reduction of 60 to 70 per cent, with no appreciable difference in removal of B.O.D. from the two seeded tanks and the one not seeded.

Since this long aeration period and low rate of feeding were industrially impracticable, feed rates of 3,000 or 6,000 ml. per day (except Sunday) per tank were thereafter applied. Continuous operation was maintained except that the air flow was shut off for 1 hour each morning and afternoon when, on the 3,000 ml. per day rate, 1,500 ml. of the supernatant liquid was siphoned off from each tank and 1,500 ml. of fresh settled waste added and aeration resumed.

In making the analytical and control tests, the procedures outlined in "Standard Methods" were, in general, followed. All B.O.D. tests were made using standard water seeded with ½ per cent fresh settled sewage. Other determinations made were: dissolved oxygen by the sodium azide modification of the Winkler Method; pH with a Beckman Model G pH meter; turbidity with a Jackson turbidimeter; suspended solids on a filter paper in a Buechner funnel. The Gooch crucible method for suspended solids was used for several months but the large amounts of clay in combination with organic matter made this method unsatisfactory.

Attempts were made to improve the efficiency of the biological process by pH control, additions of ferric chloride, and additions of mineral nutrients. By continuous addition of CO_2 the pH of the liquid waste being aerated was held at approximately 7.7. Also a method was developed whereby addition of H_2SO_4 maintained the pH of the waste between 7.2 and 8.2, but in neither case was there any improvement in B.O.D. removal, so pH control was discontinued. Additions of different amounts of $FeCl_3$ were made to the wastes being aerated, but the B.O.D. removal was not improved, and there was a definite deterioration in effluent quality; hence the use of $FeCl_3$ was abandoned.

Additions were made of the "Standard Methods" B.O.D. nutrient salts in quantities such that the concentrations of the salts in the waste liquor were about 5 times the concentrations available in B.O.D. dilution water. Results indicated about 10 per cent improvement in B.O.D. removals. Later experiments showed that $(NH_4)_2SO_4$ when used alone provided the same improvement as all of the other salts combined, also that $NaNO_3$ when added to supply equivalent amounts of N was equally effective. Apparently the settled deinking waste is somewhat deficient in available N for maximum biological activity. A summary of the effects of adding nitrogen to waste at 3,000 ml. per day loading is presented, as follows:

Average Results July 1, 1946 to Mar. 17, 1947	Mixed Liquor			B.O.D. Removal	
	Settleable Solids (%)	Suspended Solids (p.p.m.)	S.V.I.* (ml.)	Raw to Settled (%)	Raw to Final (%)
Control tanks, no nitrogen added....	20.9	2935	79.1	17.2	74.9
Tanks receiving 1.0 p.p.m. or more of nitrogen.....	11.6	2982	39.0	17.2	84.1

* S.V.I. = Sludge Volume Index = Volume occupied by 1 gram of sludge after settling the mixed liquor 30 minutes.

Two other tables of data from addition of nutrients experiments and two sets of graphs, one set showing the effects of nitrate addition, the other the effect of pH on B.O.D. removals, are given.

The similarities and differences between this biological process for treatment of deinking waste and the activated sludge process for the treatment of domestic sewage are discussed. Operations which would probably be involved if this aerobic biological process was applied to a full scale installation at a deinking mill are outlined.

Conclusions stated are: Over-all B.O.D. removals, raw waste to settled effluent, of 64 to 80 per cent were obtained at an aeration period of 19 hours without addition of any nutrient salt. The addition of 12.5 p.p.m. of sodium nitrate (2.1 p.p.m. of N) to the settled waste increased the overall B.O.D. removals to 77 to 91 per cent at the same aeration period; results at aeration periods of 9.5 hours were, respectively, 55 to 70 per cent and 64 to 80 per cent B.O.D. removals. The addition of 12.5 p.p.m. of $NaNO_3$ appears to be justified because of the increase in B.O.D. removal and the more compact sludge produced. Addition of larger quantities of $NaNO_3$ had little further effect on treatment efficiencies.

There was no correlation between strength of raw waste and per cent B.O.D. removal, but a gradual reduction in quality of the effluent was noted as the pH of the settled waste increased from 8.4 to 9.0. The process as developed appears to be practical, but further research is needed as to optimum aeration period. Pilot plant investigations will be necessary before cost figures can be obtained and methods of disposal or utilization of the by-product sludges worked out. Some pilot plant work is already under way to obtain data on the effectiveness of treatment and the economics of the process when applied to a continuous flow-through plant.

W. W. Hodge

Possibilities of Recovery and Utilization. By F. W. Mohlman. *Proc., Am. Soc. C. E.*, **74**, 1052–61 (Sept., 1948).

The course of industrial practice is characterized by progressive recovery as salvage of products once wasted. The author discusses losses in the packing-houses (and recovery of grease); wool scouring plants; breweries (recovery of yeast); distillery and alcohol (recovery of solids from "slop"); corn products (recovery of solids for feed); pulp and paper (investigations under way on recovery of yeast and alcohol); by-products coke (salvage of phenol); chemicals, plating and pickling (under investigation for practical process for handling); oil refineries (recovery of oil). There is little opportunity for salvage from tanneries, laundries, dairies, or canneries.

Many recoveries are useful, but may not be profitable. However, salvage is being classed as part of the factory operation.

Langdon Pearse

Effect of Stream Pollution Legislation and Control. By D. E. Bloodgood. *Proc., Am. Soc. C. E.*, **74**, 1048–51 (Sept. 1948).

In Indiana, pollution cases developed around 1856, and in 1866 an industrial complaint occurred. The present contribution from industry is estimated at 55 to 60 million equivalent population. After discussing Federal and State legislation, Bloodgood concludes:

(a) Federal legislation can coordinate activities of State stream pollution control units.
(b) State legislation should authorize a board of control, with broad powers.
(c) Industry should have no objection to well-written, reasonable laws on stream pollution control.
(d) Suitable industrial wastes disposal methods can be developed by legislation initiating necessary studies.

Langdon Pearse

Use of the Dropping-Mercury Electrode for the Continuous Measurement of Dissolved Oxygen in Flowing Water. By W. A. Spoor. *Science*, **108**, 2807, 421–422 (1948).

Description of an apparatus for measuring dissolved oxygen is given using the dropping-mercury electrode with an open bridge in a reservoir containing a saturated solution of KCl and calomel. The reservoir is set at such a level that the pressure of the solution on the bridge is slightly greater than that driving water into the electrolysis cell. With this modification of the calomel electrode, the limiting current remains constant for as long as a week.

H. Heukelekian

Formation of Cyanogen Chloride During Chlorination of Certain Liquids, and Toxicity of Such Liquids to Fish. By L. A. Allen, N. Blezard and A. B. Wheatland. *The Journal of Hygiene*, 46, 2, 184–193 (July, 1948).

The paper gives experimental proof to the earlier observations that certain sewage effluents become highly toxic to fish with doses of chlorine much smaller than are required to give residual chlorine. It was suggested that this toxicity was mainly due to a compound formed from chlorine and thiocyanate which was derived from gas liquor discharged into the sewage. The thiocyanate, although oxidized by secondary processes, may be found in the effluents from such plants.

Rainbow trout were used for testing the toxicity. The substrate was either effluent from trickling filters diluted with water or water to which various concentrations of gas liquor or thiocyanate were added. These were chlorinated to below residuals. Ten rainbow trout were placed in the tank and the time required for each fish to lose its balance and turn over was noted. The toxicity for each fish was expressed as 100 times the reciprocal of time in minutes required for the fish to lose their balance. D.O. was determined to insure that the toxicity was not due to lack of oxygen.

Tests with a large number of sewage effluents revealed that those which became toxic by the addition of chlorine below the residual point were those to which gas liquor had been discharged. The addition of 1 to 5 p.p.m. of chlorine to dilute (.05 to .15 per cent) gas liquor, with chlorine demand of 5 to 14 p.p.m., reduced the survival time of the rainbow trout from over 24 hr. in the control to as low as 65 minutes. Thiocyanate solution with 5 to 15 p.p.m. CNS when chlorinated with increasing amounts of chlorine (doses much smaller than the chlorine demand) showed increasing straight line relationship with toxicity.

Reaction between chlorine and cyanide or thiocyanate gives cyanogen chloride (4 molecules of chlorine reacting with one molecule of thiocyanate). Cyanogen chloride is known to have exceedingly toxic properties. It was concluded that the toxicity of chlorinated effluents was due to the formation of cyanogen chloride from thiocyanate and chlorine.

Treatment of a dilute solution of thiocyanate with an amount of chlorine less than the total quantity capable of reacting with the thiocyanate present resulted in the formation of less than the theoretical quantity of cyanogen chloride. There was a marked loss of cyanogen chloride upon standing with excess halogen.

The concentration of cyanogen chloride formed, and the resulting toxicity, by the action of chlorine on thiocyanate, was found to depend not only on the concentration of the two reactants but on the presence of other interfering substances which competed for chlorine. Glucose, phenol, and acetic acid do not interfere; peptone reduces the amount of cyanogen chloride formed slightly and catechol more markedly. Sodium sulfide, cystine and cysteine reacted so readily with the chlorine that comparatively little cyanogen chloride was formed.

Aeration reduces the toxicity of chlorinated effluents and thiocyanates. As aeration of chlorinated thiocyanate solutions progressed toxicity was decreased and was eventually eliminated after 4 hours. Aeration of chlorinated sewage effluents also reduced the toxicity, but in no case was the toxicity entirely removed. Evidence suggested such effluents contained other substances which reacted with chlorine to form a toxic compound. Fish exposed to such substrates containing this second toxic compound did not recover when transferred to fresh water, although they recovered when cyanogen chloride was the only toxic agent.

Aeration resulted mainly in the physical displacement of the cyanogen chloride in solution, as was shown by the capture of the exhaust air and the detection of cyanogen chloride in it.

Immersion of fish in a 1 per cent solution of sodium thiosulfate did not protect them subsequently when exposed to cyanogen chloride. Neither was the toxicity appreciably affected by the addition of small amounts of thiosulfate to the solution in which the fish were immersed nor to the chlorinated solution of thiocyanate. But if the quantity of thiosulfate added was sufficiently large the fish did not die and the cyanogen chloride was destroyed. During the tests with fish

lasting far less than 3 hours the amount of cyanogen chloride lost from solution is not appreciable. The threshold toxicity of cyanogen chloride is about .08 p.p.m. CNCl.

H. HEUKELEKIAN

Concentration of White Water Sludges. I. Sludge Characteristics and Some Factors Affecting Concentration. BY WILLEM RUDOLFS AND A. J. PALLADINO. *Paper Trade Journal*, **126**, 20, 31–38 (May 13, 1948).

A review of the results of previous investigations on the general nature of sludges with comparisons between the properties of the white water and of strong domestic sewage, and the sludges obtained therefrom, is given.

In this investigation three general techniques for thickening of white water sludges were explored: concentration by gravity settling, by flotation, and by vacuum filtration. The properties and factors studied were: nature and characteristics of the sludges; effects of surface area, sidewall, time, initial concentration, temperature, mixing, coagulation and flocculation, and deaeration on concentration. The studies were made to indicate possibilities of improved methods of concentration.

The white water sludges used were obtained from three paperboard mills, designated A, B, and C, and one tissue mill, D. The paperboard sludges in most cases were coagulated from the mill wastes with alum in doses ranging from 0.5 lb. per 1,000 gal. to 2.0 lb. per 1,000 gal., and with activated silica in doses equal to 0.1 the alum doses. Sludge samples from mills A and B were collected also by 2-hour plain sedimentation.

The sludges were collected from: mill A after the white water had passed through a wire cylinder save-all; mill B before passage through a save-all; mill C from the plant recovery unit, having been coagulated with alum and activated silica; mill D by induced flotation of the fiber particles in the mill waste, the waste consisting mainly of short fiber material. For settling containers 500-ml. graduates were generally used, but in the experiments on effect of surface area and sidewall, 250-ml., 500-ml., and 1,000-ml. graduates were used. Sludge volume readings were made at staggered intervals of from 10 min. to 6 hours and at approximately 24-hour intervals thereafter, up to 142 hours.

Analyses of sludge characteristics included pH, total, suspended and dissolved solids content, and ash; also in some cases acidity, alkalinity, and turbidity. The characteristics of the sludges varied widely. The characteristics of the sludge obtained by alum coagulation of white water differed only slightly from those of the sludge obtained by 2-hour plain settling of the white water, except the former were of slightly higher solids concentration in each case.

The different stages in concentration by gravity settling—free, hindered, "zone of compression," and compaction—are discussed in relation to the settling quality of the suspensions and the hydraulic characteristics of the container. In the sludges studied in this investigation the free settling phase was not encountered. Comparisons are made between the settling characteristics of the white water sludge from a paperboard mill and return activated sludge of about the same suspended solids content; the latter concentrated more rapidly. The equivalent particle size diameter of 2,000 p.p.m. activated sludge is given as 1 mm. The length of fiber in Sludge A4 was found by microscopical examination to vary from 0.045 to 4.5 mm. The greater colloidal matter content of white water sludge and probably its smaller equivalent particle size account for the difference in settling rates. Of the hydraulic characteristics affecting settling, side wall area and surface area are probably the most important. Experiments along this line gave results which showed that average total differences of 29 per cent in white water sludge volume reductions were obtained. Of this difference 11 per cent was attributable to sidewall effect and 18 per cent to surface area effect. Investigation of the concentration rates of sludge from the lime neutralization of oxidized pickle liquor indicated that sidewall effect was practically negligible with this sludge and that surface area accounted for any discrepancy.

The procedures followed in the several series of experiments are given. The data obtained are tabulated, also presented in ten sets of curves. The results are dis-

cussed in relation to prior research on similar types of sludges, and possible practical applications. A summary given of the conclusions reached is as follows:

1. In general, white water sludge will concentrate at relatively low rates more slowly than activated sludge of the same solids concentration; the effectiveness of gravity settling depends principally on the sludge nature and initial concentration.

2. For a sludge of specific nature, subsidence in the hindered settling phase is more rapid with sludges of lower initial concentration than with sludges of higher initial concentration; hence for purposes of re-use of sludge or disposal by means other than lagooning, the period of efficient concentration by settling is shorter for sludges of lower initial concentration.

3. Greater subsidence velocities are achieved at higher sludge temperatures due to decrease in viscosity and specific gravity of the settling medium. Therefore, frequent sludge removals are preferable where the white water is treated by sedimentation.

4. The sludge solids concentration attained at some stage in the hindered settling phase may be greater in the case of sludge of initially lower concentration. This indicates also the feasibility of frequent sludge removal from white water treatment units.

5. The buoy-effect of gases coming out of solution impedes settling by attachment of gas bubbles to sludge particles. In sludges removed at high temperatures from white water treatment units, this effect is at a minimum since the tendency is toward lower temperatures, i.e. greater solubility of dissolved gases.

6. The volume of sludge can be readily decreased in 3 to 6 hours to 25 to 40 per cent of the original by gravity settling or flotation, depending on the initial concentration; further compaction is primarily a function of time and temperature.

W. W. HODGE

Concentration of White Water Sludges. II. Physical and Chemical Methods. By WILLEM RUDOLFS AND A. J. PALLADINO. *Paper Trade Journal*, **126**, 21, 27–32 (May 20, 1948).

Extensive series of experiments were carried out to ascertain the effects of four coagulants and pH on the concentration of white water sludge by flotation, induced flotation by supersaturation with air, and by evacuation; also, results obtained by vacuum filtration. The sludges were obtained from different paperboard mills by coagulation of white water or from plant recovery units, and from watery sludge collected at a tissue mill. The analyses made and sludge characteristics were similar to those presented in Part I of these investigations.

The details of experimental procedures are given. The coagulants used were ferric sulfate, ferric chloride, lime and alum. Doses applied ranged from 5 lb. per 1,000 gal. to 360 lb. per 1,000 gal. Flash mixing was employed. In some tests the pH values were not adjusted; in others, the pH was adjusted to values varying from pH 2 to 12. The mixing was followed by quiescent settling and sludge volume readings were taken up to 48 hours.

Doses of 5 lb. per 1,000 gal. of any one of the coagulants caused little more reduction in sludge volumes than was attained by settling alone. A lime dose of 180 lb. per 1,000 gal. produced a 29 per cent reduction in sludge volume in 1 hour. Doses of 20 lb. per 1,000 gal. of $FeCl_3$, or of lime, caused no increase in settling rates. The effect of pH on sludge volume production was small, an amount exceeding 5 per cent being attainable only at extreme pH values and after 6 hours' settling time.

Concentration of the sludges by flotation was accomplished by using calcium hypochlorite; by means of supersaturation with air using high speed mixing with a Waring Blender for 3 minutes followed by quiescence for from 15 minutes to 1 hour; and by evacuation. . The Sveen-Pederson and the Dorr ADKA are two types of industrial save-alls in which operation involves saturation of the white water with air and subsequent release of air bubbles at a lower pressure. Chemicals are added to produce flocculation. These flotation processes are particularly effective in concentration of slurries consisting of fibres of small particle size which settle very slowly; hence, much of the experimentation with this technique was performed with that kind of sludge. Doses of calcium hypochlorite ranging from 50 to 1,000 p.p.m. were added in the dry state to samples of

sludge. Maximum sludge volume reductions by flotation with the 1,000 p.p.m. dosage were 15 per cent in 1 hour, 40 per cent in 4 hours, and 50 per cent in 24 hours; with 500 p.p.m. doses, reductions equalled ½ of these values; doses below 500 p.p.m. yielded small and erratic results. With doses of 20,000 p.p.m. and pH adjusted from 5 to 1, the sludge volume reductions did not exceed 20 per cent in 1 hour and tended to be slightly higher at the lower pH values.

More than 30 tests on different types of sludges were made using supersaturations with air by high speed mixing alone, and in combination with additions of calcium hypochlorite, in one series of 100 p.p.m. and 1,000 p.p.m., with pH adjusted to 6 before mixing; in another series, of 1,000 to 5,000 p.p.m. with pH at 5 or 6. With a sludge which did not concentrate on quiescent settling, supersaturation with air followed by quiescent standing showed a 35 per cent average sludge volume reduction in 5 minutes, 50 per cent in 15 minutes, and 55 per cent in 1 hour. The turbidity of the effluent varied from 400 to 600 p.p.m. Rapid remixing of the subnatant liquor accomplished a total sludge volume reduction of 60 to 65 per cent, and gave a sludge of 2.5 per cent solids concentration which was not appreciably concentrated further by another rapid mixing. Additions of 100 p.p.m. of calcium hypochlorite as a flotation aid increased somewhat the efficiency of this process; additions of 1,000 p.p.m. were no more effective than the 100 p.p.m. doses. Greatest concentration occurred when the hypochlorite was added before mixing, but the turbidity of the subnatant liquors was least (100–150) when the chemical was added after mixing. However, with pH adjustment to 5.0 and a 5,000 p.p.m. dose of hypochlorite, flotation yielded a sludge of 2.59 per cent consistency and a subnatant liquor to 200 p.p.m. suspended solids. Inducing flotation by carefully controlled and slow increase of vacuum from 5 to 25 in. of mercury was found effective in reducing sludge volumes by 67 per cent in ½ to ¾ hour, but results were not readily reproducible.

In the vacuum filtration tests a 16-sq. in. experimental filter leaf covered with nylon filter cloth was used. The cycle of operations consisted of 60 seconds immersion of the filter leaf in the continually well mixed sludge and a 60-second period in which the vacuum usually dropped off from 25 in. of mercury to 15 inches. The filter cakes were blown off with compressed air and their moisture contents and thickness were determined. The volume and turbidity of the filtrates were measured. Of the filter aids used, lime and Celite 545 gave the best results; mixing with the sludge and precoating the filter methods were applied. Based on the 2-minute cycle, filtration rates of 30 gal. per sq. ft. per hr. were attained; the sludge solids concentration was about 3.5 lb. per sq. ft. per hr. exclusive of filter aid weight. The moisture content in the filter cakes obtained by use of filter aids was about 70 per cent, without filter aids 80 per cent, but the weight of water per unit weight of sludge removed was lower in the cake when no filter aid was used.

A 15-minute backwashing interval seemed adequate to maintain satisfactory filtration rates. The effects of variations in filtration procedures, in pH, and in the use of lime and alum as coagulants prior to filtration are described and discussed. Nine tables of experimental data and 3 sets of graphs are given.

Flotation is more effective than gravity settling for dewatering of white water sludge and the buoyant effect of the gases coming out of solution can be greatly increased by supersaturation, artificially induced. Lime was a better filter aid for paper tissue sludge than diatomaceous earth, but the latter is applicable when re-use of fibre is desired. Alum is more effective than lime in vacuum filtration of paperboard sludge. In general, settling or flotation and vacuum filtration applied successively could decrease the moisture content of the sludge from 99 to about 70 per cent, thus decreasing the water-to-solids ratio from 99 to 1 to 2.3 to 1. However, it is necessary to have a slurry of at least 1.5 to 2.0 per cent solids by virtue of solids concentration per se, or by addition of filter aid in order to obtain a filter cake of sufficient thickness to make vacuum filtration feasible. Four references are given.

W. W. Hodge

Report upon Trade Refuse (Coal Trade) in the West Riding. The West Riding of Yorkshire Rivers Board. By J. H. Garner. 97 pp. (1948).

This report deals with pollution from collieries and the coking and by-products plants associated therewith. There are 105 collieries, of which 79 have coal washers. 30 premises have coking plants, of which 5 have tar distillation plants. 55 collieries have water-softening plants. On 76 premises, boiler blow-down refuse is produced.

Several plants flocculate and clarify the coal-washing water, for re-use. The slurry may be recovered for use also.

The pollution from coking and by-products plants may be prevented (a) by using waste to quench coke; (b) by irrigation upon burning spoil banks; (c) by discharge into old mine workings; (d) by discharge into large ponds for dilution before use for colliery purposes; (e) by direct mixing with water for coal washing; (f) by storage and sale to ammonia distillers; (g) by discharge into public sewers.

The Rivers Pollution Commission of 1868 and the Royal Commission on Sewage Disposal (1898–1915) concluded that pollution by coal washing refuse could be prevented and profit derived from recovery of fine coal. Settling, with coagulation where required, should reduce the suspended solids below 40 p.p.m.

Coal washing processes are of two main types, trough washers and hopper washers. The trough washer is inclined from 1 in 4 (for coarse material) to 1 in 50. From 900 to 1,350 Imp. gal. per ton of coal are used in large plants handling 100 tons per hour, and 1,100 to 2,000 Imp. gal. per ton in smaller plants. In hopper washers, the water was introduced at the bottom. The hopper type has given way to a dense media (Chance) type of washer in a mixture of fine sand, and water is used to separate the coal and dirt.

The most widely used types in Great Britain are known as jigs or bashes, in which compressed air is used to pulsate water through the material to be washed, which moves forward over screens.

When particles are under 1/32 in., separation by washing is difficult.

The Baum washer includes recirculation of water and automatic removal of slurry. It consists of a deep conical bottomed tank (around 168,000 Imp. gal. capacity), with appropriate piping. When emptied for cleaning, settling tanks and drying tables are provided. To hasten the drying of slurry in tanks, well points have been used, placed on the tank bottom, surrounded by coarse sand.

To increase flocculation and settling, starch and lime (1 lb. starch and 2 lb. lime per 10 tons coal) or starch and soda have been used.

In some cases the sludge is dewatered on a rotary vacuum filter. A distinct advance is an entirely closed washing system (Unifloc), producing clean water and a slurry cake with 25 to 30 per cent moisture.

Even with recirculation, about 22 Imp. gal. of make-up water are required to replace loss with each ton of coal washed. On average, about 1,500 Imp. gal. of water are circulated per ton of coal washed. The type of water available should be studied.

A program for prevention of pollution by coal washing effluents is required.

Data are given on 105 collieries.

Langdon Pearse

Continuous Strip Pickling. By Edwin D. Martin. *Blast Furnace and Steel Plant*, **36**, 1089–94 (Sept., 1948).

In connection with an investigation of means for increasing the pickling rate of strip steel, a waste pickle liquor disposal process was developed which recovers ferrous sulfate monohydrate, utilizes rinse waters, and avoids any waste water discharge.

The investigation of pickling practice disclosed that an increasing concentration of ferrous sulfate retarded pickling rate at low acid concentrations (5 per cent by volume), but as the acid content of the bath was increased the effect of ferrous sulfate became less and less until, at 18 per cent acid, there was no decrease in pickling rate even when the bath was saturated with ferrous sulfate. As acid concentrations were increased above about 23 per cent by volume, the retarding effect of ferrous sulfate appeared again. Pickling temperature was 190°–210° F.

This finding, which was studied extensively in the laboratory, was the basis for a new method of pickle liquor treatment

integral with the pickling process. A flow diagram of the process is as follows: The spent pickling solutions, containing 18.5 per cent sulfuric acid by volume and 66 grams iron per liter, are pumped from the final pickling tanks of the continuous strip picklers through a common surge tank to the evaporator. The solution is combined with approximately five times its volume of recycle liquor from the crystallizer and introduced through spray nozzles into the stream of hot gases from a Petro-Chem furnace. These gases, at 2,000° F., effect the flash evaporation of water from the solution. The recycle liquor acts as a crystal seeding agent for the spent liquor. The concentrated spent liquor is removed from the gases by a centrifugal separator and drains to the crystallizer. The furnace gases, after leaving the separator, are washed and cooled by rinse water from the pickling lines, to recover entrained acid.

The concentrated liquor in the crystallizer is heated to 220° F. by injection of superheated steam. Fresh acid (60° Be. H_2SO_4) is added to this concentrated liquor to replace the acid lost in the picklers. This brings the acid concentration in the crystallizer to about 32 per cent by volume. At the elevated temperature and high acid concentration, ferrous sulfate monohydrate crystallizes from the solution. The suspension of salt passes down around a baffle from the feed section of the crystallizer to the main volume of liquor. Complete crystallization occurs after contact between liquor and suspended crystals for 2 hours. The crystals are allowed to settle, and the clear supernatant acid solution is drawn off to the dilution tank. A portion of this solution is recycled to the evaporator. The heavy slurry is drawn from the crystallizer to a centrifuge. The dewatered crystals, after washing, are discharged to an air conveyor which effects the final drying.

The filtrate from the centrifuge is discharged to the dilution tank. The concentrated acid solution in this tank is diluted to the desired strength by the addition of wash and rinse waters. The diluted and regenerated acid solution, containing 23.5 per cent sulfuric acid and 14 grams of iron per liter as ferrous sulfate, is pumped back to the pickling lines for reuse. The actual value of the acidity of the regenerated solution will depend on the quantity of solution withdrawn from each pickler per unit time. This quantity is determined by over-all economic factors.

The proposed pickling system would consist of the continuous pickling lines with a regeneration plant. The treated solution from the recovery plant is pumped to the first tank of each pickling line. The flow of the solution is concurrent with the travel of the strip from one pickle tank to another. It is then pumped from the last (usually, the fourth) tank to the regeneration plant. The temperature in tank No. 1 is maintained at 205° F., while the temperature in the other tanks is decreased from 200 to 190° F. successively to raise the solubility limit for ferrous sulfate. There is a decrease in the acidity and an increase in ferrous sulfate in each successive tank. No additions of acid are made to these tanks since the acid added in the recovery plant is equivalent to the decrease during pickling. Drag-out loss of acid is practically eliminated through the use of all rinse water in the recovery system.

A study of this pickling system with its associated regeneration of acid will demonstrate its flexibility and sound economic basis.

(Abstracter's Note: This is the concluding article in a series of three. The first two trace the development of continuous strip pickling in an interesting manner. They will be found in the July and August issues of *Blast Furnace and Steel Plant.*)

RICHARD D. HOAK

Potomac Basin Zoning Report. BY THE WEST VIRGINIA WATER COMMISSION. 40 pp. (July 1, 1948).

This report is the second in a series of such reports for the purpose of supplying definite information concerning the value of West Virginia's surface streams and where and how they are being seriously polluted.

The report covers 14 per cent of the state's surface area and was completed during 1946 and 1947. The basin is classified into zones based on pollution conditions found during the survey period. The criteria limits for dividing the streams

into zones have been based on the use of the water for public supply, the propagation of fish life, and recreational purposes.

Priority tables for the installation of waste treatment are included in the report together with detailed charts, graphs, tables and maps prepared from the survey data. Also included are statements of the Commission's program for pollution control, its criteria for zoning or classification of streams, and its policies for effecting pollution abatement. For a discussion of these statements see the abstract of the Commission's previously published Kanawha River Basin Report, THIS JOURNAL, 20, 2, 350 (March 1948).

Copies of the report may be obtained from the West Virginia Water Commission, 1806 Washington Street, E., Charleston 1, West Virginia.

S. C. MARTIN

Chemical Character of Surface Waters of South Carolina, 1945–47. Bulletin No. 16. BY WILLIAM L. LAMAR. South Carolina Research, Planning and Development Board, Columbia, South Carolina. 24 pp. (1948).

This bulletin is the second which has been prepared by the agency in cooperation with the U. S. Geological Survey. Bulletin No. 15, "Ground Water Investigations in South Carolina," published in 1946 was the first of the series. Bulletin No. 17, "Surface Water Supply in South Carolina," was to be available in September 1948.

Bulletin No. 16 is primarily a tabulation of the chemical characteristics of South Carolina surface waters. Copies are available free of charge to those interested.

S. C. MARTIN

Professional Opportunities

PERSONNEL NEEDED FOR WATER POLLUTION CONTROL

A need exists for qualified technical personnel to aid in carrying out the comprehensive national water pollution control program pursuant to the Water Polution Control Act of 1948, Carl E. Schwob, Chief of the Division of Water Pollution Control, Public Health Service, Federal Security Agency, has announced.

Mr. Schwob said that reserve commissions in the Public Health Service and civil service appointments may be applied for until further notice by qualified sanitary engineers, biologists, bacteriologists and chemists. Those accepted in the Reserve Corps will have an opportunity to make application for appointment into the Regular Corps of the Public Health Service when regular corps examinations are announced. The Commissioned Corps officers have the same pay and allowances as officers of the other (military) services.

The salaries for positions in the commissioned corps for those with dependents range from $3391, Junior Assistant Grade (2nd Lt.) to $6056.50, Senior Grade (Lt. Col.). These salaries will be higher for those with prior military service. The above positions may also be filled through civil service appointment. Positions of P-3 ($4479.60 per annum) to P-7 ($8509.50 per annum) are available for sanitary engineers, and up to P-6 ($7432.20 per annum) in the other specialties.

Further information may be obtained from Chief, Division of Water Pollution Control, Public Health Service, Washington 25, D. C.

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Texas Water and Sewage Works Association	College Station, Texas	Feb. 6–10, 1949
New Jersey Sewage Works Association	Stacey-Trent Hotel, Trenton, New Jersey	March 23–25, 1949
Virginia Industrial Wastes and Sewage Works Association	Natural Bridge Hotel, Natural Bridge, Va.	March 31-April 1, 1949
Arizona Sewage and Water Works Association	Hassayampa Hotel, Prescott, Ariz.	April 1–3, 1949
Montana Sewage Works Association	Johnson Hotel, Great Falls, Mont.	April 7, 1949
Arkansas Water and Sewage Conference	Marion Hotel, Little Rock, Ark.	April 11–13, 1949
Kansas Sewage Works Association	Bizonite Hotel, Hutchinson, Kans.	April 21–22, 1949
Pacific Northwest Sewage Works Association	Bellingham, Wash.	May 11, 1949
Michigan Sewage Works Association	Park Place Hotel, Traverse City, Mich.	May 23–25, 1949
New England Sewage Works Association	Bristol Country Club, Bristol, Conn.	May 25, 1949
Central States Sewage Works Association	Hotel Sherman, Chicago, Ill.	June 17–18, 1949
Institute of Sewage Purification (Summer Conference)	Harrogate, England	June 20–24, 1949
Ohio Sewage and Industrial Wastes Treatment Conference	Carter Hotel, Cleveland, Ohio	June 22–24, 1949
Pennsylvania Sewage Works Association	Nittany Lion Inn, State College, Pa.	Aug. 24–26, 1949
Iowa Sewage Works Association	Hotel Kirkwood, Des Moines, Iowa	Sept. 20–22, 1949
West Virginia Sewage and Industrial Wastes Conference	Ogleby Park, Wheeling, W. Va.	Sept. 21–23, 1949
Federation of Sewage Works Associations	**Hotel Statler, Boston, Mass.**	**Oct. 17–20, 1949**
New England Sewage Works Association	Hotel Statler, Boston, Mass.	Oct. 17–20, 1949

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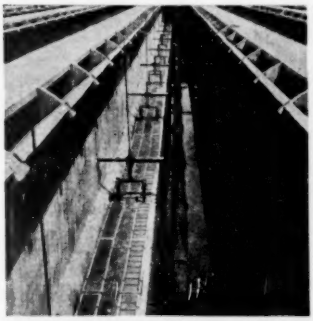

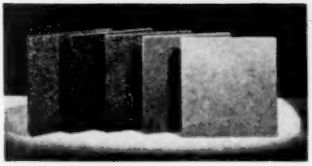
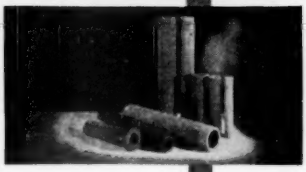

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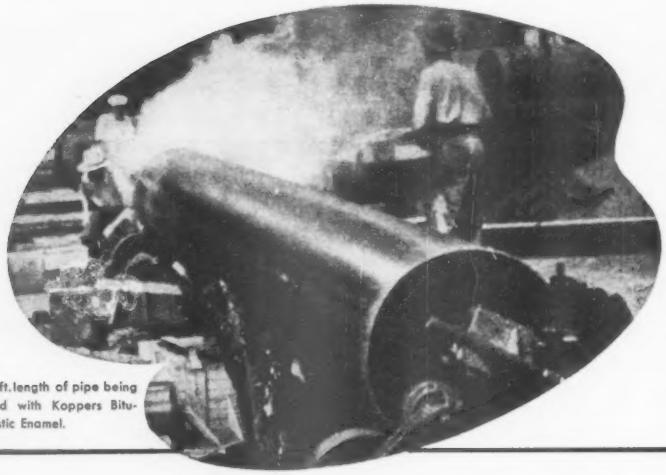

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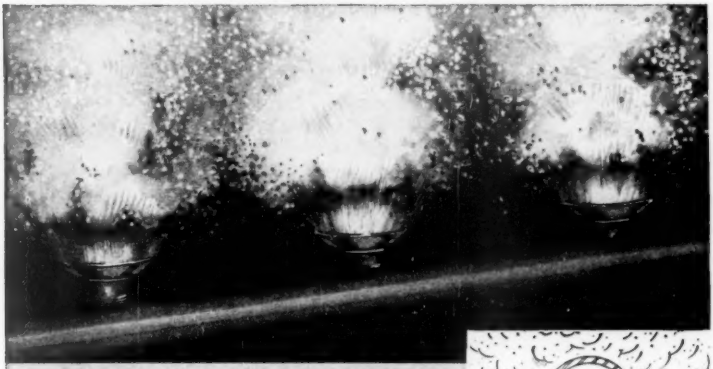

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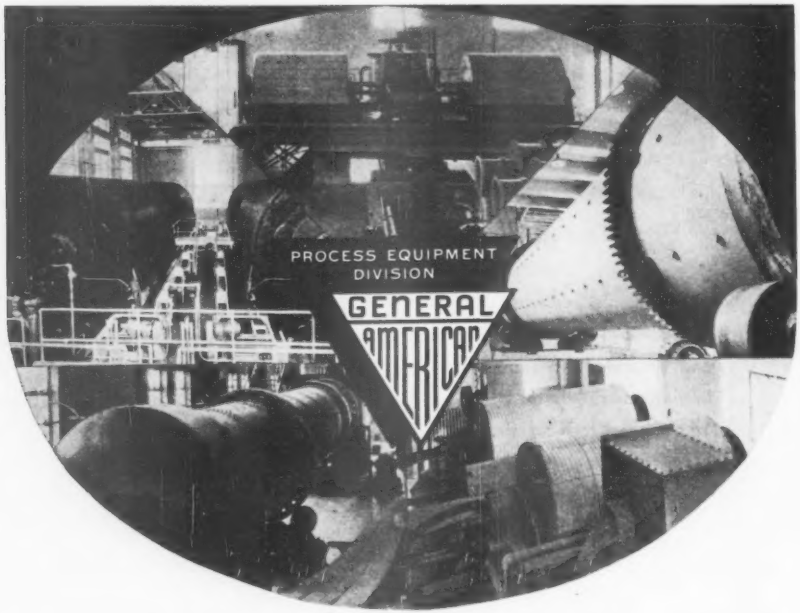

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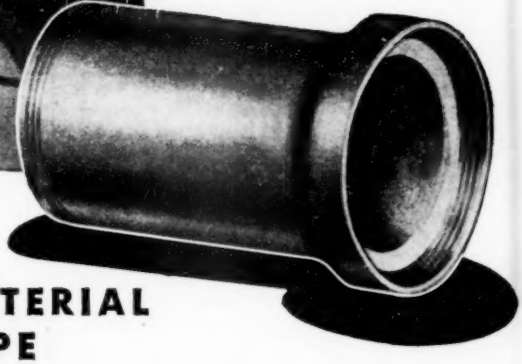

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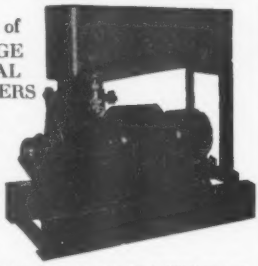

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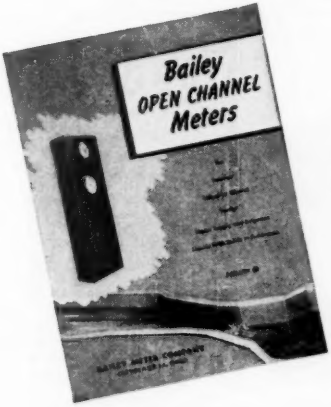

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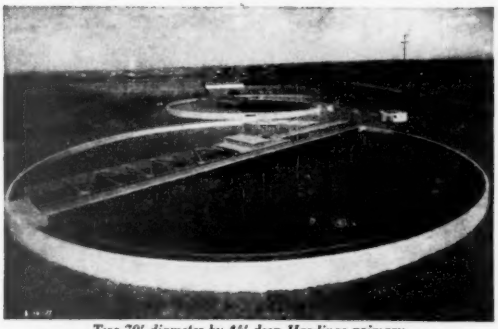

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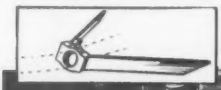

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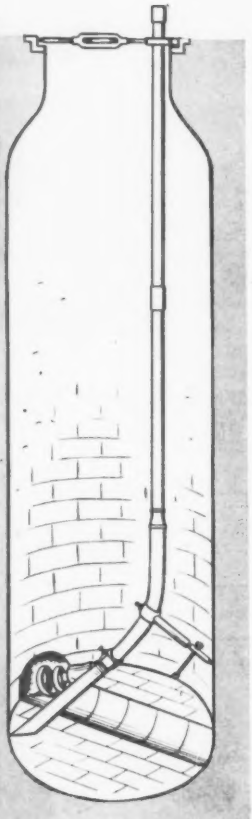

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